THE UNIVERSITY OF ALBERTA

THE QUANTIFICATION ABILITIES OF ELEMENTARY SCHOOL STUDENTS

by

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A THESIS

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled, "The Quantification Abilities of Elementary School Students", submitted by Kenneth Gordon Samuel Kellough, in partial fulfilment of the requirements for the degree of Master of Education.

ABSTRACT

The main purpose of this study was to discover the present average quantification ability levels of elementary school students with respect to the fundamental parameters of physical science: length, mass and time.

A sample of one hundred and eighty children, composed of thirty students from each grade (sixty from each the Edmonton Public, Edmonton Separate and Strathcona County school systems) was used. Each student was assigned to a high, average or low intelligence group within each grade level on the basis of an I.Q. test administered during the study.

During a forty-five minute testing session, each student was presented individually with three quantification subtests, each subtest consisting of a group of stimulus test objects variant in one basic property, a series of related questions and a set of appropriate measuring instruments. The students were each evaluated on the basis of response to the questions, selection of measuring instruments and measuring accuracy. A complete record (both written and taped) was kept of the responses and choice of measuring instruments.

The data were subjected to analyses of variance and correlations between specified variables were looked for and identified. Decisions to accept or reject hypotheses were made at the 0.05 level of significance for F and "t" tests, and at the 0.10 level of significance for Scheffé tests.

The results of the analyses indicated the following:

(1) Highly significant relationships exist among the three quantification scores and between each quantification score and the variables grade, age, general intelligence and previous experience. (2) No significant difference exists between boys and girls in quantification abilities except in isolated cases. In each of the cases where a significant difference existed, boys showed a superior quantification ability. (3) With respect to intelligence, the high I.Q. group generally performed significantly better on the quantification subtests than did the low I.Q. group. Fewer significant differences on the subtests were found between the other paired I.Q. groups. (4) The greatest differences in quantification ability were found between grade levels, a rapid growth in these abilities occurring between grades one and two, a gradual growth taking place thereafter. (5) Instrument preferences were dominated by the foot ruler and meter stick for length, postal scale and pan balance for mass/weight, and the clock and stopwatch for time measurement, previous experience being the best single predictor of choice.

The main implication of this study was that experience designed to improve quantification abilities in children should be continued, at least up to the grade six level, since no peak in these abilities is manifested before that time.

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TABLE OF CONTENTS

APPENDIXES Page

LIST OF TABLES

TABLE | Page

LIST OF FIGURES

Chapter 1

INTRODUCTION TO THE STUDY

BACKGROUND TO THE PROBLEM

> In the opinion of many people...the most valuable product of the labors of scientific men has not been the mass of knowledge thus accumulated but the method of inquiry developed, which in the last few centuries has so greatly accelerated and enhanced the scope of scientific discoveries (Kesslar, 1945, pp. 212-213).

The 1960's have been a period of accelerated evolutionary change in elementary science education. The 1969 Alberta Science Curriculum is a product of this era which had its beginnings at the famous Woods Hole Conference held under the direction of Jerome Bruner[1]. The central theme of the conference, which has helped influence subsequent science curricula was:

> Intellectual activity anywhere is the same, whether at the frontier of knowledge or in a third-grade classroom. What a scientist does at his desk or in his laboratory...is of the same order as what anybody else does when he is engaged in like activity --if he is to achieve understanding. The difference is in degree not in kind (Bruner, 1960, p. 14).

This idea, which is central to the AAAS "Science - A Process Approach" and to many other curriculum projects, also resulted in several fundamental changes in the Alberta Science Curriculum, the most important of which was the addition of

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[1] Jerome Bruner's The Process of Education is the report of the Woods Hole Conference organized by the National Academy of Sciences in 1959 to discuss the improvement of science teaching in American schools.

'process skill' development, the 'modus operandi' of the scientist, to program objectives:

> As a result of science instruction, the elementary school pupil should:
> (a) develop the ability to inquire, i.e., ability to think and investigate science through the use of process skills...(Curriculum Guide, 1969, p.5). (See Appendix A for a complete list and description of the processes).

The implicit suggestion is simply that when pupils behave (at their level of development, of course) as scientists do, they experience science rather than just learn about it. Classrooms become challenging laboratories rather than just lecture theatres. Children become active participants rather than just passive receptacles for knowledge.

THE PROBLEM

Because the development of process skills constitutes an important part of the Alberta program of studies, it is necessary that both curriculum and student evaluation be carried out with this objective in mind. Here considerable difficulty exists. The traditional procedure of measuring pupils' acquisition of factual science information by the paper and pencil test, though straightforward, is inadequate for measuring behavioral skills.

Few tests purporting to measure process skills are available -- and those that are, are mainly of the 'testimonial' variety, the author claiming that specific process skills are measured, without providing justification for such claims.

Decisions leading to changes in curriculum organiza-

> tion have been made largely by pressure, by hunches, or in terms of expediency instead of being based on clear cut theoretical considerations or tested knowledge (Taba, 1962, p. 384).

This very real problem is recognized and noted in the Alberta Curriculum Guide (1969):

> If the new approach in science is to succeed, a radical change in evaluation procedures is essential (Curriculum Guide, 1969, p. 9).

William B. Reiner's question, "Are we meeting the challenges in testing brought on by recent extensive curriculum changes in elementary...school science...?" is definitely warranted (Reiner, 1966, p. 335). Likewise, Munson's response which indicates we are not, is backed by ample evidence: "As rapid progress is being made in the development of techniques for teaching science process, a void has been created in evaluation procedures" (Munson, 1967, p. 126).

This need indicates the worth and justification of selecting a single process skill, defining it in behavorial terms, and analysing and describing the level of behavior reached by pupils in each of the elementary grades with respect to it. In this way we can, at the same time, determine the process abilities of pupils from grades one through six for specific process skills and can accumulate the data necessary for the construction of valid tests of process ability.

The Department of Elementary Education at the University of Alberta has initiated a systematic program which is designed to measure process skills through the elementary grades. The program utilizes a direct approach, i.e., "direct

observation of the behavior of students working on tasks designed to require each of the process skills for their solution" (Blackford, 1970, p. 3).

The first phase of this program, involving one of the basic process skills -- "classification", was completed by C.D. Blackford[2] in 1970. The present study constitutes a continuation and extension of this program and involves another of the basic processes of science - "quantification".

Blackford and Wilson indicate the need for answering the following questions with regard to each of the process skills: (1) How can we go about measuring the ability of the pupil in each process skill? (2) At what stage in his development is the child able to handle such processes? (3) At what stage does formal training in each process cease to be necessary? (Blackford and Wilson, 1970).

Before we can attempt to answer these questions, we must first measure the present ability of our student population with respect to each process skill. This pre-assessment is necessary in order to select priorities, to plot the course of teaching, and to insure proper utilization of classroom time (Perkes, 1969).

THE PURPOSE

The purpose of the present study was to determine the

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[2] Blackford, C.D., The Classification Abilities of Elementary School Students, Unpublished M.Ed. Thesis, University of Alberta, 1970.

behavioral abilities of students from grades one to six with respect to one of the basic process skills -- "quantification". More specifically, the purpose of this study was:

1. To discover the present level of ability to quantify, in terms of the physical parameters of mass, length, and time, for a sample of children in each of three I.Q. groups in each of the grades one through six.

2. To discover if a relationship exists between the ability to quantify and (a) grade level, (b) age, (c) sex, (d) general intelligence, (e) verbal ability, (f) numerical ability, (g) spatial relations ability, (h) reasoning ability, (i) perceptual speed ability, (j) socio-economic status, (k) previous experience, and (l) teacher's perception of the child's ability in science.

3. To discover some of the difficulties children experience in carrying out tasks involving quantification.

4. To discover the procedures most commonly used by children in quantifying, and to discover whether these procedures change with grade level.

5. To identify any plateaus reached during the growth of the ability to quantify, assuming such growth does occur, in pupils from grades one through six.

SIGNIFICANCE OF THE STUDY

With the shift in emphasis from information for its own sake to a concern for process, inquiry, and active pupil participation in science, new techniques in evaluation have been eagerly sought. In order to make the many decisions

which are necessary before any curriculum can be rightfully implemented, means for evaluating success in achieving objectives must be developed. "It is well to aim for new outcomes in science teaching, but we must also consider how we shall know whether we are achieving them" (Munson, 1967, p. 27).

This study was undertaken with the hope that it would:

1. Provide teachers with criteria by which they may judge the quantification abilities of their students in grades one through six.

2. Indicate at which grade levels the various emphases on quantification skills will be most productive.

3. Indicate any relationships which may exist between quantification abilities and (a) grade, (b) age, (c) sex, (d) general intelligence, (e) verbal ability, (f) numerical ability, (g) spatial relations ability, (h) reasoning ability, (i) perceptual speed ability, (j) socio-economic status, (k) previous experience, and (l) teacher's perception of the child's ability in science.

4. Give some indication of the quantification procedures children in different grades think of and prefer to use.

5. Indicate any difficulties children experience in carrying out quantification tasks.

6. Prove useful as an aid in the preparation of practical techniques for evaluation of quantification abilities in the classroom setting.

7. Indicate the nature and sequence of quantification exercises and activities which can be employed most profitably, from the point of view of developing process skills in elementary science.

DEFINITIONS OF IMPORTANT TERMS

1. Quantification Ability. "...increasing competence in measuring length, weight, area, volume, and rate of change of the physical world" (Curriculum Guide, 1969, p. 8).

2. Measurement. "A process of associating with some feature of the world of experience a number which describes this feature in terms of some unit" (Pelletier, 1966, p. 7).

3. Length. The extent from beginning to end in a spatial field (Lovell, 1961, p. 104).

4. Mass. Mass will be defined in terms of weight since weight undoubtedly describes the most efficient way to determine the masses of ordinary physical objects (Jammer, 1961, p. 105) -- The force produced by the effect of the Earth's gravitational field upon a given mass.

5. Time. The interval through which an action, condition, or state continues (Lovell, 1961, p. 76).

6. Length Quantification Score. The total score obtained on the length subtest of the quantification instrument.

7. Mass Quantification Score. The total score obtained on the mass subtest of the quantification instrument.

8. Time Quantification Score. The total score ob-

tained on the time subtest of the quantification instrument.

9. Intelligence. Intelligence is designated as low, average, or high, according to the score obtained on the S.R.A. Primary Mental Abilities 2-4 Test (grades 1,2,3) or 4-6 Test (grades 4,5,6). For the purpose of this study, students from the first to thirty-third percentile in each grade will be designated the low I.Q. group, students from the thirty-fourth to sixty-seventh percentile in each grade will be designated the average I.Q. group, and students from the sixty-eighth to ninety-ninth percentile will be designated the high I.Q. group (percentile norms provided by S.R.A.).

10. Verbal Ability. Refers to the score obtained by the subjects on the 'Verbal Meaning' subtest of the S.R.A. Primary Mental Abilities Test.

11. Numerical Ability. Refers to the score obtained by the subjects on the 'Number Facility' subtest of the S.R.A. Primary Mental Abilities Test.

12. Spatial Relations Ability. Refers to the score obtained by the subjects on the 'Spatial Relations' subtest of the S.R.A. Primary Mental Abilities Test.

13. Reasoning Ability. Refers to the score obtained by the subjects on the 'Reasoning' subtest of the S.R.A. Primary Abilities Test.

14. Perceptual Speed Ability. Refers to the score obtained by the subjects on the 'Perceptual Speed' subtest of the S.R.A. Primary Mental Abilities Test.

15. Socio-economic Status. Refers to a numerical

index assigned to each subject, obtained by classifying the family wage-earner's occupation according to a scale designed by Blishen (1967).

16. Previous Experience. Refers to a score assigned to each subject on the basis of his declared experience with the measuring instruments provided for each quantification subtest. For each instrument, 2 points were assigned for personal experience, 1 point for vicarious experience, and 0 points for no experience. The 'previous experience' score for each quantification subtest equalled the sum of the scores assigned for each instrument available for that subtest.

HYPOTHESES

1. There is no significant relationship between length quantification score, mass quantification score, and time quantification score. There is no significant relationship between each of these quantification scores and: (a) grade, (b) age, (c) sex, (d) general intelligence, (e) verbal ability, (f) numerical ability, (g) spatial relations ability, (h) reasoning ability, (i) perceptual speed ability, (j) socio-economic status, (k) previous experience, and (l) teacher's perception of the child's ability in science.

2. There is no significant difference between boys and girls in:

(a) Length quantification score,

(b) Mass quantification score,

(c) Time quantification score,

in each of the grades one through six.

3. There is no significant difference between low, average, and high I.Q. students in:

(a) Length quantification score,

(b) Mass quantification score,

(c) Time quantification score,

in each of the grades one through six.

4. There is no significant difference between grade levels in:

(a) Length quantification score,

(b) Mass quantification score,

(c) Time quantification score,

from grade one through six.

5. There is no significant interaction between grade level and I.Q. with respect to:

(a) Length quantification score,

(b) Mass quantification score,

(c) Time quantification score.

6. There is no significant interaction between grade level and sex with respect to:

(a) Length quantification score,

(b) Mass quantification score,

(c) Time quantification score.

LIMITATIONS

1. All students in the sample have not been involved with the 1969 science curriculum, which emphasizes the process of inquiry, for the same length of time. Their experience with it varies from one to three years. After this program

has been in effect for a full six years, a similar study may produce different results for the quantification task for a comparable sample of students.

2. Although the test of quantification ability used has construct validity, no attempt was made to determine its reliability.

3. The possible influence of the experimenter may have fluctuated to some extent over the two month testing period due to minor but inevitable changes in the nature of the questioning procedure, although every effort was made to standardize this procedure and to present the tasks in a uniform manner.

4. The schools provided by the three systems for the investigation were not randomly sampled. This was not possible as the demands of experimenters on the school systems were too great. Although schools were chosen so as to provide the best possible selection under the circumstances, a truly representative sample may not have been obtained. Care must be taken therefore when generalizing the results to populations outside the sample. A comprehensive description of the schools is provided in Appendix B, page 137 , to help interested educators decide whether the results might be applicable to their particular situation.

5. Although every effort was made to limit the effect of the teacher variable, the possibility remains that specific teacher characteristics influenced the results, limiting their generalizability. A description of the science

teachers involved in the study is given in Appendix C, page 158 again to help those interested in deciding whether the results pertain to their particular situation.

6. Because the investigation took place during the months of May and June, and because the unit on measurement is often taught near this time, a variation in scores might have resulted from the teaching, or lack of teaching, of this unit prior to the testing of any given individual or group.

7. Because identical questions are asked during testing for each of the three parameters, scores on the second and third subtests may be affected by 'test-wiseness'. The exercises involving each of the parameters were presented in a constant order to 'standardize' this effect as much as possible, with a practice session preceding the first segment of the actual test, in the hope that this might reduce the effect during the scored portion of the test.

8. A limitation which is invariably associated with a study such as this is related to the fact that <u>all</u> the variables that may influence science achievement can rarely, if ever, be completely accounted for. For example, such influences might include: teacher effectiveness, general school climate, individual student "self" perceptions, influences of other curricular areas, peer influences, classroom methodology, and extra-curricular influences to name but a few.

THE EXPERIMENTAL SETTING

The experimental design is reported in detail in Chapter 3. However, a brief overview is given here for the

purpose of orientation.

In order to determine the feasibility of this investigation, a sample of thirty children was chosen for a pilot study. For the study proper, a sample of one hundred and eighty children was chosen at random from the student populations of the twelve schools assigned to the investigation from each of: The Edmonton Public School System, the Edmonton Separate School System, and the Strathcona County Number 20 School Division (which is adjacent to the City of Edmonton). Fifteen subjects were chosen from each school participating in the investigation in such a way that two or three pupils from each of the grades one through six were tested. A total of thirty pupils per grade, (fifteen boys and fifteen girls) were tested. An ability test, devised specially for this investigation, involving both manipulative skills and oral responses to questions, was administered in a 45 minute individual interview. An I.Q. test was administered to each subject at a later date.

The questions for the quantification ability test required verbal answers with, for some questions, accompanying manipulation of measuring instruments on predetermined stimulus objects. The individual testing situation and the simply worded oral questions and instructions were chosen because of the wide potential range of abilities represented in the sample, and because of the nature of the skill being tested. The responses of the subjects were recorded on special data collection sheets (See Appendix D, page 166), the interviews

also being taped for later analysis.

Testing for the pilot study was carried out in March, 1971. Testing for the investigation proper was carried out from April 19, 1971 to June 24, 1971.

OUTLINE OF REPORT

The nature of the problem under investigation having been presented, a review of the literature related to the study will be presented in Chapter 2. Chapter 3 contains a detailed description of each aspect of the experimental design, the methods and materials used in the study, and the statistical analysis used to test the hypotheses. The results of the analysis of data are reported in Chapter 4, together with a descriptive analysis of performance on the instrument used. Finally, a summary of the results of the study, including conclusions, implications and suggestions for further research is presented in Chapter 5.

Chapter 2

LITERATURE REVIEW AND THEORETICAL CONSIDERATIONS

Pertinent research literature and theoretical considerations relating to this investigation may best be examined under three general headings: research pertaining to process skills and their evaluation; theoretical considerations concerning the quantification process; and the fundamental parameters of physical science: length, mass, and time.

PROCESS SKILLS - THEIR DEVELOPMENT AND EVALUATION

> Each area of knowledge has at least two main characteristics: it has its own fund of acquired information and a specialized method of inquiry, or a strategy of acquiring that knowledge. From this it follows that the study in a subject area should result, first, in the acquisition of skills, attitudes, and "disciplined habits necessary for the discovery of new knowledge", and second "in the acquisition of the most useful fund of information possible for mastery within the limits of the time available for the subject" (Downey, 1960, p. 254, in Taba, 1962, p. 172).

The general form of elementary science curricula in the last decade has reflected this point of view (Tyler, 1962). Curriculum objectives which formerly included only the substantive or content dimension of science, have now begun to incorporate the syntactical or process dimension as well. This redistribution of emphasis recognizes the true nature of all disciplines (Schwab, 1961).

This shift in emphasis necessitates a comparable shift in evaluation procedures.

> Perhaps the most central and often the least used function of evaluation is to validate the hypotheses upon which the curriculum is based...(Taba, 1962, p. 314).

Although much effort has been expended in the attempt to restructure the elementary science curriculum (Kessen, 1964), and in the production of appropriate related materials (Lockard, 1970), the development of means for evaluating the degree of success of these efforts has not received due emphasis. Taba in referring to this lack of necessary focus, states:

> In the light of the recognized importance of its role, it is surprising to note several deficiencies in present evaluation programs. First there is a great discrepancy between the scope of the objectives of curriculum and the scope of evaluation (Taba, 1962, p. 312).

Elsewhere she adds:

> These matters cannot be settled on the basis of philosophical arguments alone. One needs to determine what changes these innovations actually produce and what effects they have on the total pattern of educational outcomes...Careful evaluation has not been made of the innovations of the past, nor is it being made today (Taba, 1962, p. 314).

A concern for the paucity of instruments capable of satisfactorily assessing the worth of emerging science curricula is shared by many educators (Lombard, 1965; Munson, 1967; Reiner, 1966; Smith, 1969; Stauss, 1970).

Stauss (1970, p. 247) has posed the following pertinent questions:

> How often do we take a critical look at the evaluation instruments being used? Is it not quite possible that our tests may be poorly constructed? Do the instruments we construct and use really measure what we think we are trying to teach?

It has long been realized that the measurement of the acquisition of factual material, a relatively straight forward procedure, is no longer sufficient. Science educators agree

that "Facts alone do not constitute science" (Shamos, 1960). However, significant advances beyond this stage in evaluation have proven to be difficult to achieve.

A major problem which exists centers upon the construction of validated tests which measure pupil performance in handling process skills, the formulation of such tests having lagged far behind the need for them.

Analysis of science tests commonly used for assessment purposes, such as STEP (Sequential Test of Educational Progress) and TOUS (Test on Understanding Science), reveals the presence of a predominance of recall questions from the substantive dimension and only a modicum of problem-solving and reasoning questions allied to the syntactical dimension (Hukins, 1963; Mokosch, 1969). An examination of questions taken from teacher-produced science tests also indicates that problem-solving is almost totally neglected (Newton, 1961; Hedges, 1966).

Tests developed by Nelson and Mason (A Test of Scientific Comprehension, 1963) and Butts and Jones (TAB Science Test, 1966) examine children as inquirers in science to some extent, but the use of such tests, restricted as they are to the upper elementary grades (grades 4-6), reduces their utility, especially as we need to be able to evaluate the development of the fundamental process skills from at least the first grade on:

> Science - A Process Approach deals sequentially with the special skills and competencies needed for serious science study. These include obser-

> vation, classification, space/time relations, using numbers, communication, measurement, inference and predicting in the primary grades...(AAAS Commission on Science Education, 1968).

Another shortcoming of these tests is their limited range, and their inadequacy in evaluating many of the skills commonly employed by scientists. Thus we have carefully formulated programs, but no means of evaluating their effectiv-ness. Even relatively recent attempts to produce a process measuring instrument such as The Test of Science Processes (Tannenbaum, 1969), have not been followed by satisfactory validation procedures. The dilemma which educators currently face is compounded of the need, on one hand, for 'convenient' paper-and-pencil tests and the need, on the other, for tests which truly measure behavioral skills.

It has become apparent then, that different methods are needed for the appraisal of process abilities. The suggestion has been made that teachers should use subjective methods for evaluation in this area (Alberta Department of Education, 1969; Munson, 1967), the use of checklists (Alberta Department of Education, 1969), anecdotal records (Navarra, 1955; Alberta Department of Education, 1969), personal interviews and other free response techniques (Thier, 1965), quality ratings of oral student initiated questions (Suchman, 1962) and student self-evaluation and peer assessment (Kowitz, 1968) being among the methods recommended.

Although use of these procedures are not without problems (Watson and Cooley, 1967, p. 305; Reiner, 1966),

the development of techniques which measure process skills has, to some degree, been realized through their implementation. Possible areas for further investigation have also been indicated. However, Reiner's challenge draws attention to the fact that these introductory attempts require continuing and intensive development:

> A challenge to devise such observational techniques that are simple, economical of time, practical and yield useful data, has not been satisfactorily answered up to now. The need is great (Reiner, 1966, p. 336).

This challenge has been taken up by Blackford[1] who asserts that a necessary initial step in devising adequate evaluation techniques is the formulation of criteria which will provide a basis for making each of the previously mentioned subjective judgements (Blackford, 1970, p. 2). Blackford suggests that these criteria can be defined only by reference to direct observation of student behavior during the performance of tasks which require the use of specific process skills for their solution (Blackford, 1970, p. 3).

The present general lack of knowledge in the critical area of evaluation of process skills has stimulated this investigation, which is centered upon the production of a satisfactory instrument for assessing one of the fundamental process skills, "quantification", the formulation of criteria

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[1] For a comprehensive review of the evaluation of process skills, see Chapter 2 of Blackford, C.D., The Classification Abilities of Elementary School Students, Unpublished M.Ed. Thesis, University of Alberta, 1970.

for the use of this instrument and its application in the elementary grades.

THE QUANTIFICATION PROCESS

All of science is based upon an ability to carry out accurate measurements. Thus, the emphasis on measurement in many elementary science programs, is an important feature which is based upon a fundamental and vital factor (Ploutz, 1966). This 'quantitative approach', which is basic to science, is easily understood if one regards science as a 'creative endeavor' by which man attempts to provide explanations and predictions regarding the many aspects of his environment. He accomplishes this through a search for order and regularity (Thier, 1970). Quantitative data is the basis for this search[2]. A fairly general definition of the term 'quantify' is "to determine quantity of, measure, express as a quantity". _The Alberta Curriculum Guide for Elementary School Science_ in dealing with this process, makes the following point under the heading, "Quantifying":

> The desired pupil behavior is increased competence in measuring length, weight, area, volume and rate of change of the physical world (p. 8).

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[2] Comprehensive discussions of the role of quantification in the quest for knowledge are to be found in Daniel Learner, ed., _Quantity and Quality_, New York: Free Press of Glencoe, 1961; and Harry Woolf, ed., _Quantification - A History of the Meaning of Measurement in the Natural and Social Sciences_, New York: Bobbs-Merril, 1961.

Examples following this operational definition are illustrative:

> Distinguish objects by using such terms as heavier and lighter; identify relative weight by lifting; use a balance to distinguish heavier from lighter objects; use standard units of weight; explain effects of gravitation and inertia; measure the weight of various objects; describe differences in weight, identify, state and demonstrate differences in perception of weight.

How the quantitative approach relates to the limitations and capabilities of the young learner is an important question which must be answered by those concerned with the construction of a meaningful science program for the elementary school (Thier, 1970, p. 64; Swartz, 1964, pp. 349-355), and the need for determining when the developing child would best profit from formal instruction in measurement must also be taken into account in any such program.

One of the most natural, direct, and active learning experiences involves measurement, a primary example of the application of the number system to the real world. Measurement has formally been defined as "a process of associating with some feature of the world of experience a number which describes this feature in terms of some unit". (Pelletier, 1966, p. 7). This use of number may also distinguish quantitative from qualitative description but, according to Helmstader (1970), the distinction depends upon the way in which symbols are attached to categories.

> If the symbols are used only as labels to distinguish among different categories and nothing more, the data are all qualitative; but if the symbols are used not only to distinguish among categories but to infer a relationship of order among them

> as well, then the description is quantitative (Helmstader, 1970, p. 178).

This idea of numerical relationship is especially important in the areas of mathematics and physical science.

In the world of experience there are two kinds of numerical events that can be observed -- those which are continuous and those which are discontinuous.

Discontinuous events, or sets, are intermittent, that is, each element is separate from the others. For example, a box of marbles or a bag of apples is discontinuous because the components are individually distinct and, as such, can be easily counted. This counting of the components produces a number.

Continuous events or sets, on the other hand, involve those things which are uninterrupted in time, sequence or form. A mass of clay or a quantity of milk provide good examples of sets because the elements which make up these aggregations are not discrete. They cannot be readily counted. Instead, general characteristics of such sets are determined by measurement.

In comparing the two different procedures, Piaget points out:

> The ability to measure develops later than the number concept (which is the inclusion of categories and of serial order) because it is more difficult to divide a continuous whole, such as an object being measured, into interchangeable subunits than it is to count a set of objects that are separate and discrete from each other, such as beads or blocks (Piaget, 1953, p. 78).

Stages of Development of Measurement Ability

The stages through which a child advances as he develops an understanding of the measurement concept have been thoroughly researched and reported by Piaget and his collaborators (1960). Three stages are evident. The first stage is characterized by the absence of measurement in the strictest sense, and is also distinguished by the absence of operations necessary for true measurement to take place. During this stage, the child makes a perceptual comparison of the object only, and no attempt is made to use measuring instruments, even when they are readily available. The child simply estimates, utilizing a single criterion such as an endpoint for reference. Other pertinent factors, for example the object's position, are rarely taken into consideration.

The intermediate stage in the development of measurment ability is represented by a transitional period. During this phase the child begins to use measuring instruments such as parts of his own body, but he does so incorrectly. The resultant comparison is inaccurate because a coordinated reference system for interpretation is absent and the transitive property of the equals relation (if A = B and B = C, then A = C) has not yet fully developed. Understanding is reached only after a lengthy period of trial and error.

During the final stage of development, true measurement is realized and the skill becomes an operational feature of the child's repertoire. The child has learned mentally to subdivide the object to be measured into parts, thus

realizing the whole is the sum of its parts, and has also learned to apply one part (represented by the measuring instrument) to another (represented by the object being measured) the appropriate number of times, thereby building a system of units.

Fundamental Measurement Concepts

Measurement, then, is a quantitative description of one object using another as a reference. Pertinent principles related to the process include: comparison, conservation, unit iteration, standardization of units, precision, and accuracy.

Comparison

A common mistake teachers make in introducing a new style of measurement is to start at the point where a standard has been devised; they thus deprive the student of learning an inherent property of measurement, that of comparison.

As mentioned, the three developmental stages which a child traverses in his quest for measurement ability may be distinguished by the modes of comparison typical of each. Initially the child makes gross perceptual comparisons, but because all the necessary factors are rarely taken into consideration, the resulting estimate is generally incorrect. However, the child's use of the terms "more" and "less" and "same as" lay the foundation for describing one quantity by means of its relationship to another. In the transitional stage, measuring instruments are first used, though incorrectly, for comparison. Attempts to use various parts of the body

as a measuring instrument dominate the early phases of this stage. As the child advances, however, more appropriate measuring tools are sought in order to improve the comparison. Late in this stage the child begins to comprehend the idea of transitivity in a common measure, and even the role of a measuring unit. In the final developmental stage, the child is able to use any appropriate object as a common term, or as a measuring instrument, and his insight into the principle of comparison is complete.

Conservation

A second principle fundamental to, and prerequisite for, understanding measurement is that of conservation. Conservation refers to the acknowledgement of the invariance of a durable property of an object regardless of transformations of other of its properties, and is the primary characteristic of the concrete operational level of intellectual development (Piaget, 1952). Lovell and Ogilvie in their study of this concept conclude:

> The concept of conservation or invariance of substance is an important one. A quantity such as a lump of plasticine, a collection of beads, a length or a volume can be used by the mind only if it remains permanent in amount and independent of the rearrangement of its individual parts. This notion of invariance is indeed essential to any kind of measurement in the physical world (Lovell and Ogilvie, 1960, p. 109).

Similar opinions have also been expressed by Flavell (1963), Piaget (1952), Dodwell (1960), and Elkind (1967).

In conservation, as in comparison, three developmental

stages may be recognized. The first stage is characterized by the absence of conservation. The child at this stage believes that the quantity of a given object or volume of material gets larger or smaller as its configuration or shape is changed. The second stage of development again involves a state of transition in which conservation is partially understood. On a trial and error basis the transitional individual is able to say that the quantity remains constant as configuration or shape changes, but his dependence on perception confuses the issue in many cases. In the final developmental stage, the individual realizes that a quantity remains constant even though visible transformations take place, and logical thought, not perception, is the basis for the correct answer. The phenomenon of reversibility is also understood by the individual at this stage:

> The unique and pervading importance of the conservation or invariance concept is that the most elementary forms of reasoning, whether logical, arithmetical, geometrical, or physical, rest on the principle of invariance of quantities (Inhelder, 1963, p. 41).

Although Piaget questions whether children should be given measuring experience before the concept of conservation is attained, many educators believe that children acquire this concept as a result of direct experiences involving measurement (Biggs and MacLean, 1969, p. 125). Thus, although the existence of a general relationship between conservation and measurement is generally acknowledged, the educational implications of the relationship remain unresolved.

Unit Iteration

A third principle basic to measurement is that of unit iteration.

> According to Piaget, Inhelder, and Szeminska, true measurement becomes possible when a part belonging to a whole is compared to the remainder by successive superposition of the part on the whole. This is known as unit iteration and may be accomplished with the part itself or with a common measure used transitively (Beilen and Franklin, 1962, p. 607).

Piaget concludes that unit iteration is a synthesis of the subdivision operation (the object being measured translated into the units of the measuring instrument) and the change of position operation (the movement of the measuring instrument along the object being measured).

Because this principle is based upon conservation, the transitive property of the equals relation, and an arbitrary division into subunits (realizing that the whole is the sum of its parts), iteration is not realized until the final stage of development of measurement ability. The attainment of unit iteration must be realized if the use of measuring instruments is to become meaningful for the child.

Standardized Units

A fundamental principle in the attainment of measuring ability is the realization of the need for standardized units.

Advancement from the initial stage, where quantities were only informally compared (bigger than, smaller than, etc.), to the stage of choice of a unit by which one quantity

can be described in terms of another (how much bigger or smaller), is a significant development, as this is the development which relates quantification (the use of numbers) and measurement. The use of unconventional units is a first, and common, step in this direction and should be encouraged. There comes a time, however, when the need to communicate <u>exact</u> information becomes apparent. Agreement between individuals on common units of measurement facilitates this interaction. For example, the basic requirements of measurement (Wilks, 1961, pp. 5-12) are more easily realized if standardization of units is adhered to:

> 1. Making a measurement must be an operationally definable process. That is, a measurement process must be defined by a specifying set of realizable experimental conditions and a sequence of operations...which will yield the measurement. The basic reason for such a requirement is to make the measurement process as objective as possible so that different individuals can obtain comparable results.
>
> 2. The outcome must be reproducible. Repeating the process should yield measurements in "reasonable agreement" with one another.
>
> 3. The measurement process must be valid or accurate, that is, the process must yield "true measurements" of the object being measured. The numerical value produced by the process must approximate the true value of the quantity being measured as determined by some independent and valid procedure.

<u>Precision and Accuracy</u>

The concepts of precision and accuracy are fundamental to the measurement process and unless these concepts are closely attended to, the value of the resultant measurement is questionable indeed.

A great difference exists between 'precision' and 'accuracy'. Precision refers to the limits imposed upon a measurement by the unit used and by the instrument selected. "Accuracy is a matter of not making mistakes. It can be obtained only with care and reasonable procedures of repetition and checking" (Swartz, 1969, p. 5). For example, the length of a room could be measured with a yardstick to a precision of a few sixteenths of an inch but the measurement could still be inaccurate by one whole yard because the number of times the yardstick had been laid end to end had been miscounted.

All measurements are approximations. There is no such thing as an "exact measurement". Thus, the comparison between the "true value" of a measurement and the "closest possible measurable value" using a particular unit, precision that is, is meaningful. The comparison between the "closest possible measurable value" and the "actual measured value", accuracy that is, though important, is quite another thing. Both are demanded in the measurement process.

The individual's grasp of the concepts of 'precision' and 'accuracy', a grasp which is not possible until the final stage in measurement ability has been reached, is shown by his choice of appropriate measuring instruments for the particular tasks he encounters which involve measurement.

The Utilization of Concrete Experiences in the Development of Measurement Ability

The traditional approach to quantification in many classrooms has been questioned. Swart (1967) charges that,

although we claim to subscribe to the principles of: (1) fruitful instruction being based on meaningful experience; (2) learning being best facilitated by proceeding from the concrete to the abstract; (3) easiest and most lasting learning coming from doing -- measurement is commonly taught vicariously and abstractly.

It is unfortunate that vicarious experience and abstract discussion is so common in the classroom, for measurement, above all, involves the direct comparison of physical objects, and is therefore a very concrete type of activity. For this reason it forms an admirable basis for direct manipulative experience in the elementary school, because children in the first six grades are, for the most part, at the concrete operational level of intellectual development. Educators such as Almy (1966), Bruner (1968), Hunt (1961), Piaget (1964), and Dienes (1959), wishing to capitalize on the learning potential of children, have conducted developmental studies which have illustrated the importance of concrete, manipulative activities:

> Piaget's theory leaves no question as to the importance of learning through activity. Demonstrations, pictured illustrations, particularly for the youngest children, clearly involve the child less meaningfully than do his own manipulation and his own experimentation. While the vicarious is certainly not to be ruled out, it is direct experience that is the avenue to knowledge and logical ability (Almy, 1966, p. 137).

Newbury (1967) concludes that the learning of primary children can be enhanced if their everyday experiences, involving observation, discussion, and recording are fully utilized in a quantitative approach to solving problems.

THE FUNDAMENTAL PHYSICAL PARAMETERS

The basic parameters of the physical world are length, mass and time. Ford and Cullman note:

> Measurement of length, mass and time are similar in that the operations used in measuring these quantities make direct reference to standards of length, mass, or time. However, most physical measurements are combinations of these simple direct measurements... (Ford and Cullman, 1959, p. 3).

The 'International System of Units' labels these parameters as 'independent base units' (Ritchie-Calder, 1970, p. 19) and Feather points out that any introduction to physics should include "examining first of all the bases of measurement of the fundamental physical quantities, mass, length, and time. Derived quantities are then introduced...(Feather, 1959, p. v).

<u>The Alberta Curriculum Guide for Elementary School Science</u> suggests that the desired pupil behavior in the area of quantification is "...competence in measuring length, weight, area, volume and rate of change of the physical world" (1969, p. 8). However, all of these properties can be expressed in terms of length, mass, and time and, for this reason, the present investigation will be confined to a measurement of the child's ability to quantify in terms of these three basic parameters, each of which will now be considered in detail:

<u>Length</u>

As noted above, Alberta's current elementary science curriculum specifies increased competence in measuring length, area, and volume. However, area (amount of surface) can be

defined as $(length)^2$ and volume (amount of space) as $(length)^3$. Thus, because area and volume are not independent parameters, they will not be included in this study.

Length may be defined as "the extent from beginning to end in a spatial field" (Lovell, 1961, p. 104). Generally, it appears to be the first of the measurement abilities developed by an individual.

The task of making a linear measurement seems simple enough to an adult, on the basis of his experience, if he is provided with a measuring instrument calibrated in appropriate units. Many underlying factors which are necessary for the successful performance of this seemingly elementary task are taken for granted. Close scrutiny, however, of the technical steps necessary, help one realize the complexity of even the simplest measurement procedures.

Piaget, Inhelder, and Szeminska (1960), have carried out many interesting experiments which illustrate the development of concepts related to an understanding of length and measurement. One of their ingenious experiments, based on spontaneous measurement, included the use of a tower on a table. The child was asked to construct a similar tower on another table of a different height, separated from the first by a screen around which the child could walk, and over which he could see. The child was provided with paper, sticks, rulers, and all other necessary materials, but he was not instructed in their use. The experimenters observed three stages through which children passed in their development:

The first stage, which occurred in children under four and a half years of age, was characterized by non-conservation and visual comparison. The second stage, occuring in children from four and a half to seven, was characterized by trial and error attempts to use simple measuring instruments to aid in the construction of the second tower. Transitory conservation (that is, conservation under certain circumstances) was noted, but incorrect use of measuring instruments prevented completion of the task. During the final stage from seven years of age onward, children were able to construct the second tower using measuring devices such as sticks. All the fundamental concepts necessary for completion of the task appeared then to have been mastered.

Lovell, Healey, and Rowland (1962), experimenting with English children between the ages of five and eleven, attempted to discover when conservation of length and distance would occur. Their results generally agreed with those of Piaget and his collaborators. They concluded, however, that chronological age was inferior, compared with mental age, as a predictor of successful performance of their set tasks, and also that length was more easily measured when the object was shorter than the measuring device. Thirdly, they stressed that:

> It is doubtful if children or adults can subject perception to logical thought until sheer experience of the situation gives some aid (Lovell, 1961, p. 112).

Pelletier (1966), in a study of length, found that

although none of the grade one Canadian children examined on his linear measurement test mastered all of the relevant concepts, children with higher mental ability were clearly superior in their understanding. He found that differences in sex and environment, including different treatments of measurement instruction, did not significantly affect the development of appropriate concepts.

In another Canadian research study, Liedke (1968) found that the only independent variable that was significant in predicting scores on a 'Concept of Linear Measurement Test' was intelligence.

Investigations carried out as part of the "Science Curriculum Improvement Study" project revealed that the teaching of science through direct manipulative experiences improved the children's ability to make quantitative comparisons of length, area, and volume.

Ervine (1960), recognizing the importance of determining the relationship between instruction and the acquisition of measurement operations, tested this relationship in a 'transfer of training' experiment. It was found that, for the first and third grades, the achievement of measurement ability is affected by the test itself, and that third graders are influenced further by instruction in measurement concepts.

Furthermore, Copeland (1970) has indicated that, if systematic measurement is to be "taught", it should not be presented before the latter part of what is usually the third grade, and then it should be an experimental or 'trial-and-

error' readiness type of experience, because the necessary concepts for operational understanding develop from within rather than from without.

Mass

Some confusion appears to exist in the use of the terms "weight" and "mass" as expressed in the Alberta Curriculum Guide. Mass is an intrinsic property of matter which results in the generation of a gravitational field. Weight on the other hand, is the result of the interaction between two gravitational fields (accelerations) generated by two masses. The weight of one of the masses, the smaller generally, is then defined by the product of its mass and the gravitational acceleration to which it is subjected by the larger mass. The mass of a given object does not change no matter where the mass is situated in the universe but the weight of that same object is dependent upon the gravitational field in which the object is located.

The reference to 'weight' in the Alberta Curriculum Guide would not present a potential source of confusion is reference was not also made in the Guide for the need to "explain the effects of gravitation..." the suggestion being to "use a balance to distinguish heavier from lighter objects". The question which must then be asked is 'what kind of balance?' because a spring balance indicates "weight" whereas a pan balance compares "masses". This fundamental distinction is probably too sophisticated and elusive for elementary school children to comprehend properly. In consequence, tasks in this in-

vestigation were referred to in terms of 'weight' only, although instruments capable of comparing masses were also provided. In any event, the tasks were carried out in the constant gravitational field of our local area, so the distinction which must be made between mass and weight could be ignored for the purposes of the investigation, although it is important to make such a distinction in the absolute physical sense.

According to Jammer, (1961) this is a permissable stand to take:

> Defining mass by weight is perhaps from the practical point of view a defensible method, since it undoubtedly describes the most efficient way to determine the masses of ordinary physical objects. From the didactic point of view, however, it easily lends to the confusion of mass and weight (Jammer, 1961, p. 105).

Investigations into the area of measurement of mass and/or weight are fewer in number than those encountered in the area of linear measurement.

Piaget and his collaborators (1941) claim that children, in acquiring an understanding of weight, pass through three stages similar to those observed in the quantification of length:

(1) a denial of conservation of weight;
(2) a transitional period in which conservation is understood on a sporadic basis;
(3) a firm conviction of conservation of weight.

The third stage does not, in Piaget's view, come until 9-10 years of age with respect to weight.

Experiments carried out by Lovell and Ogilvie (1961) have yielded results which are in agreement with those of

Piaget with respect to the existence of these three stages. In addition, they note that the stages are separated by transitional zones rather than by clearly defined boundaries. A general increase in the percentage of conservers of both mass and weight was also noted with maturation and with years in school.

Elkind (1961), in another systematic replication of Piagets' experiments, also obtained results which agreed closely with Piaget's conclusions, three hierarchically ordered stages again being evident.

Time

The present Alberta elementary science curriculum refers to the "rate of change of the physical world" (p. 8). This idea of rate of change is synonymous with the term 'time factor', whether rate of change of size, temperature, or speed is involved.

Typical definitions of time include "a limited stretch of continued experience"; "the interval between two events"; and "the interval through which an action, condition, or state continues" (Lovell, 1961, p. 79). The significance of time as one of the fundamental parameters of the physical world necessitates the developmental growth of an understanding in elementary school students of concepts related to time, together with the growth of an ability to make measurements involving time.

The concept of time has two main aspects -- order and duration. Order involves "sequence of events" and is

signified by such expressions as "before", "after", and "at the same time". Duration involves the intervals of time which separate events or the intervals during which events occur, and is signified by numerical units such as "seconds", "minutes", "hours", or by general terms such as "not long" or "a long time".

Considerable research has been carried out in an effort to clarify our understanding of the elementary school child's concepts of time.

Boring (1936) has suggested that time perception has five bases: (1) the child acquires some perception of the succession of how stimuli follow one another; (2) the child acquires some perception of continuity; (3) the child obtains some idea of temporal length from differing perceptions; (4) the child learns to respond to environmental signals of the present; and (5) the child acquires the ability to perceive patterns of successive stimuli (Lovell, 1961, p. 79).

Bradley (1948) suggested that knowledge of time is acquired in a general sequence: (1) time related to personal experience - by 6 years of age; (2) conventional time words used in the calendar and the organization of the week - by 8 years of age; and (3) time involving extension in space and duration - by 10 years of age. Oakden and Sturt (1922), and Pistor (1940) came to similar conclusions.

Springer (1952) has suggested the stages into which instruction may be divided in helping children to tell time by the clock. The following general sequence of stages of

time emerged from his investigation: (1) the child can tell the time by the clock first by whole hours, then by halves, then by quarters; (2) the child can set the hands of a clock; and (3) the child can explain why the clock has two hands.

Piaget's experiments (1946) showed that the child has difficulty in grasping the concept of time. At first the child's ideas of time are confused with his ideas of spatial changes. It is not until instants and points in the time continuum are coordinated in the mind that time becomes an invariant quantity independent of speed, distance and position. For certain kinds of events children below the age of eight - and for some events, children below the age of eleven - fail to conserve time.

Lovell and Slater (1960) carried out experiments similar to those of Piaget and his collaborators. The results obtained verified Piaget's finding that children do not appear initially to differentiate between time and space. They also found that accuracy in the perception of simultaneity, and in the understanding of synchronous intervals and order of events, increased with age. However, Lovell and Slater reported that the concept of time developed later than Piaget had suggested in his research, and that specific temporal concepts did not develop in all situations, and in all media, at the same age for any one child (about 9 years of age for their sample of children).

Lovell (1971) has indicated that children begin to carry out 'temporal operations', which enable them to acquire

a concept of time, between eight and nine years of age. The children:

1. Seriate events according to their order of succession; that is, ordering operations can be carried out.

2. Mark off intervals of time between ordered points on a time scale and "fit" smaller ones within the larger ones, thus carrying out the operations of subdivision and inclusion.

3. Carry out metrical operations; that is, choose time as a unit and use it as a standard for the measurement of all other intervals. Once again we have a synthesis of subdivision and displacement,...

Werner (1957) found that, for the very young child, time is embedded in a series of events - a continuum in which space and time are not differentiated.

Bradley (1948) determined that children have little understanding of the time period of 1 year until 9 years of age and Goldstone (1958) found that children 8 years and older make good estimates of 1 second when counting.

Murray (1969) discovered that the shift from nonconservation to conservation of time occurred between the second and fourth grade. He found that in young children (under 8 or 9) the concept of time is surprisingly defective.

Newman (1967) ascertained that intelligence, chronological age, and grade placement were significant predictors of an individuals ability to understand time duration. Socio-economic status was found to be a significant predictor of an individual's ability to understand verbal comparisons and measures of duration, while sex was not found to be a

significant predictor. He also discovered that comparisons of time duration were generally understood by children at the grade three level, and that measures of duration were first used satisfactorily at the grade four level. A noticeable improvement in the ability to understand comparisons and duration was also observed at the grade six level.

Variables of Possible Significance

The optimal development of process skills is most likely to occur in the laboratory, where pupils actively manipulate concrete materials and attempt to solve problems under conditions normally encountered by a working scientist.

Research carried out in the area of development of process skills must be based on hypotheses which are themselves derived from a careful analysis of operations which are basic to science and to an understanding of scientific procedure. Variables which should be borne in mind in any investigation or developmental program such as this include: the nature of the task, ability in solving problems of spatial relations, prior laboratory (or other direct manipulative or vicarious) experience, and manual dexterity. Also, the motivation of the student, sex, career aspirations, and behavior patterns of the teacher are worth careful examination (Watson, 1963, p. 1044).

It has been stated, with respect to all conceptual development that:

> Children's concepts change with increasing age, but more in the form of a gradual progression (toward

> greater accuracy or more informed understanding, perhaps) than of definite stages. The change does not occur at the same rate for all children. Indeed, some may never achieve the more advanced kinds of explanation at all, since even adults may display concepts similar to those of children. Further, no child of a particular age gives consistent responses of one type or another, but instead may give many different types of response, depending on the situation (Vinacke, 1952, p. 117).

According to Vinacke, factors related to concept formation in children include: age, intelligence, training or experience, socio-economic status and vocabulary (1952).

Thus many factors, acting singly or interacting together, are responsible for conceptual development. Research studies must heed as many of these as possible if meaningful results are to emerge.

Chapter 3

DESIGN OF THE STUDY

THE SAMPLE

The population from which the sample was selected consisted of all of the elementary students from twelve schools, four of which were from the Edmonton Public School System, four from the Edmonton Separate School System, and four from the County of Strathcona Number 20. These schools were selected by administrators from the three systems involved so as to provide a sample of students with a broad range of socio-economic and cultural backgrounds. A sample of one hundred and eighty children, stratified on the basis of sex, was selected from these schools in such a way that only fifteen students were used from each school. The fifteen students from each school included two or three children from each of the grades one through six. The number of children to be selected from each grade in each of the schools was determined beforehand so that there would be a total from all schools of thirty students for each grade when the testing was finished. All of the students in the sample were randomly selected from class lists prepared for each grade. This randomizing procedure was carried out to minimize the possible introduction of bias into the study on the part of any teacher or school. Table 1 (page 44) summarizes the distribution of students in the sample.

TABLE 1

DISTRIBUTION OF STUDENTS

IN SAMPLE

System		Edmonton Public				Edmonton Separate				Strathcona County				BOYS N	GIRLS N	GRADE N
School		1	2	3	4	5	6	7	8	9	10	11	12			
Grade One	M[a]	1	1	2	2	1	1	1	1	2	1	1	1	15		30
	F[b]	1	2	1	1	2	1	1	1	1	1	2	1		15	
Grade Two	M	1	1	1	1	1	2	2	2	1	1	1	1	15		30
	F	2	1	1	1	1	1	1	1	1	1	2	2		15	
Grade Three	M	1	2	2	1	2	2	0	1	1	1	1	1	15		30
	F	1	1	1	2	1	0	2	1	1	2	1	1		15	
Grade Four	M	1	1	1	1	1	2	2	1	1	1	2	1	15		
	F	2	1	1	1	1	1	1	2	2	2	0	1		15	
Grade Five	M	1	2	1	2	1	1	1	1	1	2	1	1	15		30
	F	1	1	2	1	2	1	1	1	1	1	1	2		15	
Grade Six	M	2	1	1	1	2	1	1	1	2	0	2	1	15		30
	F	1	1	1	1	0	2	2	2	1	2	1	1		15	
School N		15	15	15	15	15	15	15	15	15	15	15	15			
System N		60				60				60						
Total N						180										

[a] Male
[b] Female

INSTRUMENTATION

Quantification Task

Theoretical background. In order to achieve the objectives of this investigation, an individualized quantification activity was designed which consisted of three subtests, one for each of the three basic physical parameters: length, mass and time. This activity, in addition to satisfying the definition of quantification described in Chapter 1, had to satisfy other quantification requirements, the foremost of these having been indicated by Piaget (1960) and others (Coxford, 1963; Lovell, Healey and Rowland, 1962):

> ...in the field of geometrical concepts, as in many other fields, children may acquire a certain verbal farcade, or they may perform some action by rote since they have been"taught", without having the operational mobility to understand what they are doing (Lovell, Healey and Rowland, 1962, pp. 765-766).

It cannot be assumed because a child can count or measure that he understands number or measurement. A child may apply a ruler to an object, yet not understand the fundamental measurement process; therefore, questions based on the understanding of the measurement process were included in the question sequence. For example, the children were not asked directly to make measurements. Instead, questions and situations were designed so as to elicit some reference to the need for measurement. In addition, uncommon measuring devices were included in the apparatus available for the comparison of objects in a quantitative manner. For example, a rubber band was made available for the purpose of mass/weight

comparison during the 'mass' subtest. Thirdly, common measuring instruments were provided for measurement situations which were relatively uncommon for the child. For example, during the length subtest, the child was asked to measure a stick eighteen inches long with a six inch ruler. Lovell (1962) has indicated that the use of the correct procedure in this task would indicate a degree of understanding of measurement rather than rote memorization. Furthermore, Piaget states:

> The analysis of the way in which children come to discover the use of a middle term [measuring instrument] is sometimes complicated by the experiences they have had. Many subjects, while still belonging to Stage II [the transition stage], have learned how to measure; others have seen adults measuring. In these and similar cases, it is easy to distinguish between external and internal factors, because the child assimilates whatever he is shown to his own schemata of representation and only remembers what he understands (that is apart from mere parrot-wise verbal reproduction) (Piaget, Inhelder, Szeminska, 1960, p. 5).

From a scientist's point of view, other requirements of quantification skill must include the reliability and validity of the process used in making a particular measurement (see Chapter 2, page 28, for a full discussion of these requirements).

These latter requirements are more easily met than those discussed previously. In order to ensure that the reliability of the measuring processes used in this investigation was satisfactory, in the sense noted by Wilks, as well as to ensure that the results of this investigation were reliable, each child was confronted with the same quantifi-

cation tasks. For example, the children were always required to measure the length of the four inch stick with the twelve inch ruler. The validity requirement (the approriateness of the measuring procedure) is satisfied in that the procedures appropriate for the instruments provided have become 'standardized' by longstanding custom and convention.

Materials. The quantification activity used in the investigation involved a group of stimulus test objects, together with a series of related questions which were presented orally to each student. A set of instruments was also provided so that the students could carry out any measurement of the stimulus test objects which they felt to be appropriate.

1. Length Subtest: The stimulus test objects for the length subtest portion of the quantification activity consisted of five wooden sticks of equal cross-sectional area but of different lengths. From shortest to longest the lengths were: (1) blue stick - three inches (7.5 cm.); (2) green stick - four inches (10 cm.); (3) black stick - seven inches (17.5 cm.); (4) yellow stick - ten inches (25.5 cm.); and (5) white stick - eighteen inches (45.8 cm.). Other than the provision of an appropriate size range for measurement, the choice of these lengths was arbitrary. Each stick was colored differently in order to facilitate the child's description of the sticks and to improve communication between subject and experimenter.

2. Mass Subtest: The stimulus test objects for the mass subtest portion of the quantification activity included five balsa-wood blocks of uniform size: all being three inch cubes with rounded corners. An eyehook was centered in the top of each for ease of manipulation. The blocks differed in one quantifiable respect only, that of mass/weight. The dissimilarity in mass was achieved by removing a portion of the core of each block and filling the resulting cavity with varying amounts of lead shot. The resultant weights of the blocks, which were colored differently again for ease of identification and communication, were: (1) red block - two ounces (57 gm.); (2) green block - five ounces (142 gm.); (3) yellow block - nine ounces (256 gm.); (4) orange block - thirteen ounces (369 gm.); and, (5) blue block - seventeen ounces (483 gm.). Again, the choice of weights, was arbitrary, but provided a suitable range for measurement.

The apparatus available for use during the mass subtest consisted of: (1) a spring balance marked with ounce and gram scales; (2) a triple beam balance graduated in gram units; (3) a pan or trip balance with accompanying ounce weights; (4) a postal scale marked in ounces; and (5) an elastic band.

3. Time Subtest: The stimulus test objects for the time subtest portion of the quantification activity included five tape recordings of a uniform, moderate frequency tone

which was pleasant to the ear. The sounds differed from one another only in their time duration, the different durations being: (1) sound A - six seconds; (2) sound B - two seconds; (3) sound C - fifteen seconds; (4) sound D - eleven seconds; and (5) sound E - five seconds. Once again, other than providing a suitable range of time intervals, the choice of time durations was arbitrary. In addition, the sequence in which sounds of different duration were presented was decided on an arbitrary basis, but was in the order indicated above.

The apparatus available for use by the student during the time subtest included: (1) an electric clock with second hand; (2) a stopwatch; (3) a metronome; and, (4) an electric timer.

It should be noted that all the measuring apparatus mentioned was arranged randomly on a table adjoining the test area. The instruments appropriate for each of the separate subtests were in no way set apart from the other instruments by virtue of position or other reason. Miscellaneous "useless" instruments, such as a pair of pliers and a screw-driver, were also included.

To facilitate the preparation of the students for the quantification task, a two part warm-up activity was designed. The first part involved five styrofoam spheres of different diameters. In order of decreasing size, these diameters were: four inches, three inches, two and one half inches, two inches, and one and one quarter inches. A standard list of questions relating to the spheres was presented orally (see

Appendix E, page 173). The second portion of the warm-up activity included twenty-one beans, seven of each of three different sizes, also accompanied by a standard set of oral questions (see Appendix E, page 173).

A data sheet was used to record the child's responses to the quantification questions and other pertinent information about the child (see Appendix D, page 166).

Procedure: Each child was individually interviewed by the investigator, using a standard procedure. A random order was used in interviewing the students in each school.

Each interview followed a common pattern. After greeting the child and asking standard introductory questions regarding personal information (such as age and grade), in order to gain some degree of rapport, the investigator orally presented a common set of procedural instructions which were essential for the successful completion of the quantification task (see Appendix F, page 174). In order to ascertain the child's understanding of the task to be performed, as well as to minimize the dependence upon the verbal aspect of the procedural directions (these two factors being especially important in the primary grades), each child was shown the two groups of practice stimulus objects. At first attention was focussed upon the five styrofoam balls (the only obvious difference between them being size); secondly, attention was directed to the twenty-one beans (several properties such as size, color, and shape being variant). In both cases the

child was asked to describe the objects placed in front of him. After he had discovered the quantifiably dissimilar property of each set, this property was emphasized by having him first arrange the objects in some order according to the size property. This task completed, he was then asked to justify the arrangement chosen. If, during this procedure, the child did not volunteer an answer, or if he did not respond when a question was asked, he was prompted by means of a more specific question. For example, if he did not note that the objects were in some way different when asked to describe them, he was asked if any difference existed. If he answered incorrectly, for example responding 'No' to the above question, the incorrect response was noted, the correct answer was given, and the child proceeded to the next question.

This general focus on a structured deductive approach through questioning, in which continuation to succeeding questions depended upon previous answers, illustrated to the student the general format of the remainder of the interview. This particular procedure was employed so that the experimenter could find which areas in the developmental sequence of quantification ability were weak for the child, hindering further development. Care was taken during the interview, however, to elicit as much information from each child as possible, at the same time telling him as little as possible, consistent with ascertaining the optimum amount of information about the child's level of knowledge and quantification ability relative to the physical world. As noted, a careful

sequencing of questions was employed to come as close to achievement of this objective as possible.

Scoring. The evaluation of verbal responses and manipulative behaviors for the three quantification subtests of the quantification instrument was designed to measure the student's scientific understanding of, and manipulative ability in, scalar quantities, that is quantities involving magnitude only. As each question was answered by the student, the answer was recorded on the specially designed data sheet and a judgement was made by the investigator based on the accuracy of the response, or, in the case of questions involving manipulation of instruments, on the accuracy of the procedure. Final scoring was carried out at a later date, all subtests being scored in the same way. A tape recording was made of each interview in order to provide a supplement to the written record and to provide data for an analysis of the children's use of technical/scientific terminology - an analysis which is to be carried out at a later date.

A comprehensive description of the scoring procedures employed are to be found in Appendix G, page 177. However, a brief résumé of these procedures is also provided here.

It must be noted that several equally credible scoring procedures could be used and four such procedures were carried out. Their basic similarity allows one to choose a 'preferred' procedure without altering the general conclusions derived as a result of the investigation and, in fact, a computer

analysis was run in order to show that all procedures yielded essentially the same results. (For correlations between scoring procedures, see Appendix G, page 177).

The questions were scored this way:

1. Question 1 was not scored as it was designed to be an introductory question only, and required no quantification ability.

2. Questions 4 and 7 were eliminated from the final score tally because of their redundancy.

3. Questions 2,3,5,6,8 and 9, which were related to an understanding of the basis of measurement, were scored using two different procedures:

(a) Method one was based on a 3,2,1,0 scale, where 3 indicated that the correct response was volunteered before the question was asked, 2 indicated an immediate and correct response to a direct question, 1 indicated a prompted correct response and 0 indicated an incorrect response to a question. Incorrect volunteered responses were not scored; instead the appropriate question was asked, and the resulting answer was scored.

(b) Method two was based on a 2,1,0 scale where 2 indicated either a correct response or an immediate correct response (in case voluntary responses are merely an indicator of an "extroverted" personality rather than superior quantification ability), 1 indicated a prompted response, and 0 indicated an incorrect response.

4. Question 6, which concerned estimation rather than actual measurement, was regarded as being satisfactorily

answered if the estimation was within 25% of the true value and the units given were appropriate.

5. Questions 10 and 13, concerning the choice of appropriate instruments for the parameter being dealt with, were scored 1 point for each appropriate instrument indicated.

6. Questions 11 and 14, which involved the names of the instruments chosen previously, were eliminated from the final scoring as they did not measure quantification ability.

7. Questions 12 and 15, which involved measurement activities on the part of the student, were scored using two different procedures once again:

(a) Method one was based on a 3,2,1,0 scale where 1 point was given for the correct procedure, 1 point for the correct numerical value, and 1 point for use of the correct units. The second point was given only if the procedure was correct, and the third point was given only if the numerical value was correct.

(b) Method two was based on a 2,1,0 scale where 1 point was given for the correct procedure and 1 point for the correct numerical value and the correct units. Again, the second point was given only if the procedure was correct.

A 10% variance above or below the 'true' value of the measurement, or the degree of accuracy imposed by the precision of the measuring instrument, whichever was greater, determined the limits of accuracy which were regarded as being acceptable.

8. Question 16, concerning the naming of other instruments that might be utilized in similar situations, and question 17, concerning the description of procedures for determining the accuracy of a measurement, were scored 1 point for each correct response given.

9. Question 18, concerning other objects or things that might be measured in the same way as the stimulus objects were measured during the subtest, were scored 2 points for a generalized answer (for example, everything except...), 1 point for specific names of objects or things, and 0 for no response.

10. Questions 19 to 26 were not scored as they involved personal information only.

I.Q. Scores. I.Q. scores were obtained for all children involved in the study, with the exception of five, by administering a common intelligence test during the second and third weeks of June, 1971. The primary grades were tested using the S.R.A. Primary Mental Abilities Test for grades two to four. The upper elementary grades were tested using the S.R.A. Primary Mental Abilities Test for grades four to six.

I.Q. testing became necessary when it was found that each of the three systems used different intelligence tests which had been administered at different elementary grade levels. This made the comparisons and groupings of students from the different systems difficult and not as meaningful as it might otherwise have been. Blackford (1970) suggested:

> ...it would seem worthwhile to undertake further more detailed study of this relationship [between

> I.Q. and classification ability]. This would necessarily involve administering an intelligence test solely for the purpose of this study and correlating the scores obtained with those of the classification task (p.80).

His suggestion prompted the use of a common intelligence test in this investigation of the process skill of quantification. The S.R.A. Primary Mental Abilities Tests for grades two to four and grades four to six were chosen for two reasons. Firstly, the school systems involved in the investigation had never administered these particular intelligence tests to their students prior to the investigation. Secondly, the general intelligence quotient in the S.R.A. test is subdivided into five factors of intelligence or "primary mental abilities", which include: verbal meaning, number facility, reasoning, perceptual speed and spatial relations, each being measured on a separate subtest. It was felt that the norms and scores provided for each of these mental abilities would help indicate which factors of general intelligence are important with respect to quantification ability.

PILOT STUDIES

In order to facilitate the main study and in order to minimize any problems which might arise, two pilot studies were carried out in March, 1971, with children from a school not involved in the main study.

Pilot Study One. The first pilot study included twelve children. Two children (one boy and one girl) were chosen from each of the grades one through six. This pilot

study was undertaken to determine:

1. The approximate time needed for children to complete the quantification activity.

2. The type and amount of instruction needed in order to have the main task understood by children in each grade.

3. The feasibility of presenting the designed quantification task to the broad range of abilities presented by the students across all the grades in elementary school.

4. The liklihood of finding significant differences in performance of this task throughout the grades tested.

5. Administrative problems that might arise.

The results of pilot study one are shown in Table II.

Pilot Study Two. The second pilot study involved eighteen grade six pupils, each of average ability. This pilot study was undertaken to discover if the order of presentation of the three parameters on the quantification instrument had an effect on the scores obtained by comparable groups of students.

To determine the effect of this experimental factor, the eighteen grade six pupils selected were randomly divided into the following groups of three (the order of presentation of the three subtests being different for each group):

Group 1. Length subtest, mass subtest, time subtest.

Group 2. Length subtest, time subtest, mass subtest.

Group 3. Mass subtest, length subtest, time subtest.

Group 4. Mass subtest, time subtest, length subtest.

Group 5. Time subtest, length subtest, mass subtest.

Group 6. Time subtest, mass subtest, length subtest.

TABLE II

MEAN SCORES BY GRADE ON QUANTIFICATION SUBTESTS

PILOT STUDY ONE

Grade	N	Length Subtest	Mass Subtest	Time Subtest
One	2	12	9	6
Two	2	22	18.5	11
Three	2	23	15.5	18.5
Four	2	25.5	20.5	17.5
Five	2	26	26	19
Six	2	30	25.5	23.5

If a significant difference had existed among the scores obtained on the three subtests as presented to the above groups, it would have been necessary to control for this variable in the main investigation.

The results of pilot study two are shown in Table III.

On the basis of the first pilot study it was decided that:

1. The approximate time needed for completion of the quantification task was relatively constant at about forty-five minutes for each pupil for each of the six grades.

2. Completely verbal directions seemed adequate for all grades in the study. However, the word "experiment" had to be deleted from the directions because grade one and two pupils did not understand it.

3. Children from grades one through six were all able to attempt the quantification task. However, the lower grades, particularly grade one, met with some difficulty. To overcome possible frustrations which could thus result, verbal reinforcement was used to motivate all attempts made at answering the questions. The overall feasibility of the investigation was not in much doubt.

4. A general increase in mean quantification score through the grades was evident. Drops in scores from grades two to three and grades five to six in mass, and grades three to four in time, could be attributed to the small sample size and the wide range between the scores of the two subjects tested in these instances.

TABLE III

MEAN SCORES BY 'ORDER OF PRESENTATION'

ON QUANTIFICATION SUBTESTS

PILOT STUDY TWO

Order	N	Length Subtest	Mass Subtest	Time Subtest
Length Mass Time	3	19.3	18	15.7
Length Time Mass	3	16.7	21.3	16.7
Time Length Mass	3	19.3	20	17.7
Mass Length Time	3	21	18	17.3
Time Mass Length	3	17.3	16.3	13.7
Mass Time Length	3	20.3	17.3	17.7

5. A private room, furnished with two large tables and two chairs, facilitated the administration of the task most adequately. An electrical outlet was necessary for the operation of some of the apparatus.

6. The proposed data sheet needed some modification for greater ease of recording.

On the basis of the second pilot study, it was decided that the order of presentation of the subtests could possibly influence the quantification scores obtained. The differences in group means during pilot study two, which are possibly attributable to unspecified confounding variables or to chance alone, might also suggest that a relationship between the order of presentation of the subtests and quantification score variance possibly exists. Therefore, it was decided to obtain consistency by holding the order of presentation of the subtests constant (that is; length first, then mass, then time), the possibility of obtaining some bias in results due to order of presentation being recognized and accepted.

THE TESTING PROGRAM

The testing program was carried out between April 19, 1971 and June 24, 1971. The investigator travelled to each of the twelve schools and administered the quantification tests individually to each member of the sample. The testing was done in a private room in each school (usually the medical room or the guidance counsellor's office) which was as free from distractions as possible. Appointments were made with each school to carry out testing on days that did

not coincide with field trips, festivals, or other special events that may have eliminated a particular group of children from the sample; a situation which may have led to further bias in the final results.

The times involved for the completion of the various phases of the total program are indicated in Appendix H, page 179.

THE TYPE OF ANALYSIS USED

The variables associated with hypothesis #1, with the exception of the sex variable, were subjected to Pearson product moment correlations to determine their relationship, if any, with each of the quantification subtest scores. The significance of existing relationships was measured by a test for probability carried out by means of the DESTØ5 IBM 360/67 computer program. The sex variable was subjected to a point biserial correlation (Ferguson, 1966, pp. 239-242) to determine its relationship with each quantification subtest score. The 0.05 level of significance was used as a basis for acceptance or rejection of each correlation associated with the hypothesis.

Hypotheses 2,3, and 4 were subjected to a one-way analysis of variance. Hypothesis #2, comparing boys scores with girls scores, was analysed by means of a "t" test computed by use of the ANOV1Ø IBM 360/67 computer program. The decision regarding acceptance or rejection of this hypothesis was made at the 0.05 level of significance.

Hypotheses 3 and 4 were analysed by means of the ANOV15 IBM 360/67 computer program. This program carries out

a Scheffé multiple comparison of means. The 0.10 level of significance was used as the criterion for acceptance or rejection of the hypotheses. This rather low level of significance was chosen because of the extremely conservative nature of the Scheffé procedure. As Ferguson (1966) points out:

> Concern may attach to the fact that the Scheffé procedure is more rigorous than other procedures, and will lead to fewer significant results. Because this is so, the investigator may choose to employ a less rigorous significant level in using the Scheffé procedure; that is, the .10 level may be used instead of the .05 level. This is Scheffé's recommendation (1959, p. 297).

Hypotheses 5 and 6 were subjected to a two-way analysis of variance to determine the significance of interaction, if any, between grade and I.Q. and grade and sex respectively. This interaction was measured by means of a test for additivity carried out by use of the ANOV25 IBM 360/67 computer program. The 0.05 level of significance was used as a basis for the decision to accept or reject these two hypotheses.

Chapter 4

RESULTS OF THE INVESTIGATION

A statistical analysis of the data gathered for the investigation of each of the hypotheses, including analysis of variance tables, cell mean matrices and probability matrices, together with a summary of the results of the investigation will be presented at this point. The analyses were carried out by means of the IBM 360/67 'analysis of variance' and 'Pearson product moment' computer programs which have been documented and tested by members of the Division of Educational Research Services of the University of Alberta. A descriptive analysis of performance for each of the grades one through six on the quantification instrument, including item analyses for each subtest and frequency distributions for each measuring instrument, is also presented. A summary of results concludes the chapter.

STATISTICAL ANALYSIS OF THE HYPOTHESES

Hypothesis #1

A) There is no significant relationship between length quantification score, mass quantification score and time quantification score. B) There is no significant difference between quantification score and (a) grade, (b) age, (c) sex, (d) general intelligence, (e) verbal ability, (f) numerical ability, (g) spatial relations ability, (h) reasoning ability, (i) perceptual speed ability, (j) socio-economic status,

(k) previous experience, and (l) teacher's perception of the child's ability in science.

The intent of this hypothesis was to determine if any degree of relationship existed between the quantification subtest scores and the variables specified in the hypothesis above. Knowledge of such relationships could aid in the prediction of quantification ability scores for individuals taken from the same population as the sample. This hypothesis was analysed by means of the 'point biserial correlation' technique discussed in Ferguson (1966, pp. 239-242) for the sex variable, and by means of the 'Pearson product moment correlation' technique, calculated by utilization of the DESTØ5 IBM 360/67 computer program, for all other variables.

Results: The correlations between the subtest quantification scores and between each of these quantification scores and the variables specified in hypothesis #1 are presented in Table IV. Acceptance or rejection of the hypothesis was based upon significance at the 0.05 level. Each of the quantification subtest scores was found to correlate significantly with the other quantification scores. Also, the variables grade, age, general intelligence, verbal ability, spatial relations ability, perceptual speed ability, previous experience, and teacher's perception of the child's ability in science, were found to correlate significantly with each of the three quantification subtest scores. In addition, a significant correlation was found to exist between the

sex variable and mass quantification score, boys performing significantly better than girls with respect to this task. Therefore, <u>hypothesis #1 was rejected for each of these relationships</u>.

The correlations between the three quantification scores and the variables numerical ability, reasoning ability and socio-economic status were not found to be significant. The sex variable was not found to be significant with respect to the length or to the time quantification scores. Therefore, <u>hypothesis #1 was accepted for each of these relationships</u>. Table IV provides a summary of this information.

<u>Conclusions</u>: <u>Hypothesis #1</u>, dealing with the degree of correlation between the quantification subtest scores and between each of the quantification subtest scores and specified variables, <u>was rejected with respect to all three subtest scores and also with respect to the variables grade, age, general intelligence, verbal ability, spatial relations ability, perceptual speed ability, previous experience and teacher's perception of the child's ability in science. It was also rejected for the sex variable with respect to the mass subtest score, boys performing significantly better than girls in grades one and four. Hypothesis #1 was accepted with respect to the variables numerical ability, reasoning ability and socio-economic status for the three quantification subtest scores and for the sex variable with respect to the length and time quantification subtest scores</u>.

TABLE IV

CORRELATIONS BETWEEN QUANTIFICATION SCORES AND SPECIFIED VARIABLES

Variable	N	Length Quantification Score	Mass Quantification Score	Time Quantification Score
Length Quantification Score	180	1.00	.77[d]	.78[d]
Mass Quantification Score	180	.77[d]	1.00	.80[d]
Time Quantification Score	180	.78[d]	.80[d]	1.00
Sex	180	.12	.19[c]	.13
Grade	180	.73[d]	.75[d]	.72[d]
Age in months	180	.69[d]	.72[d]	.69[d]
General Intelligence	175	.52[d]	.51[d]	.51[d]
Verbal Ability	175	.35[d]	.39[d]	.35[d]
Numerical Ability	175	.01	.04	.03
Spatial Relations Ability	175	.43[d]	.42[d]	.40[d]
Reasoning Ability	89[a]	.08	.11	.25[b]
Perceptual Speed Ability	175	.26[c]	.22[b]	.23[b]
Socio-economic Status	174	.12	.08	.12
Previous Experience	180	.55[c]	.70[c]	.70[c]
Perceived Science Ability	180	.19[c]	.16[b]	.20[c]

[a] reasoning ability only measured for grades 4-6 by test used

[b] significant at .05 level [c] significant at .01 level

[d] significant at .001 level

Hypothesis #2

There is no significant difference between boys and girls in:

(a) Length quantification score,

(b) Mass quantification score,

(c) Time quantification score,

in each of the grades one through six.

The intent of hypothesis #2 was to determine whether the boys or the girls have the greater quantification abilities with respect to each of the three criterion variables. Investigation of this hypothesis was pursued by means of a 'two-tailed "t" test' carried out by means of the ANOV1Ø IBM 360/67 computer program. Acceptance or rejection of the hypothesis was based upon significance at the 0.05 level. A complete list of the mean scores for the boys and girls in each grade is given in Table V and a complete resume of the "t" values and probability levels calculated in making the comparison between boys and girls is given in Table VI.

Length Quantification Score. Significant differences in performance with respect to this variable were found to exist between the boys and girls in grade three. The "t" value of 3.042 was significant at the 0.005 level. The "t" values calculated for all other grades for the length quantification score variable all yielded probabilities that were not significant at the 0.05 level. Therefore, hypothesis #2 was accepted for grades one, two, four, five and six on

TABLE V

MEAN QUANTIFICATION SCORES FOR BOYS AND GIRLS PER GRADE

		Scores by Grade					
Variable	Sex	1	2	3	4	5	6
Length Quantification Score	BOYS	16.80	21.20	23.67	23.73	26.40	27.87
	GIRLS	16.33	21.13	19.93	23.27	25.47	27.00
Mass Quantification Score	BOYS	17.13	18.93	22.87	26.13	29.93	31.13
	GIRLS	9.73	19.93	20.93	21.60	26.40	30.47
Time Quantification Score	BOYS	12.07	19.20	21.00	24.40	28.93	29.27
	GIRLS	7.40	17.60	19.87	22.40	25.00	28.67

TABLE VI

COMPARISONS OF BOYS AND GIRLS
QUANTIFICATION SCORES
WITHIN EACH GRADE

Variable	Grade	S. Dev. Boys	S. Dev. Girls	Degrees of Freedom	T	Prob.
Length Quanti- fication Score	One	3.80	3.15	28	0.366	.718
	Two	3.65	2.53	28	0.058	.954
	Three	2.66	3.94	28	3.042	.005[a]
	Four	2.58	2.19	28	0.535	.597
	Five	3.33	2.50	28	0.867	.393
	Six	3.20	3.14	28	0.748	.461
Mass Quanti- fication Score	One	4.85	5.16	28	4.045	.001[a]
	Two	3.95	3.99	28	-0.689	.496
	Three	5.18	3.86	28	1.159	.256
	Four	4.90	3.04	28	3.045	.005[a]
	Five	3.85	4.82	28	2.001	.055
	Six	4.47	5.44	28	0.367	.716
Time Quanti- fication Score	One	5.42	4.52	28	2.562	.016[a]
	Two	7.52	6.08	28	0.641	.527
	Three	5.54	5.45	28	0.565	.577
	Four	5.82	4.82	28	1.025	.314
	Five	5.47	5.81	28	1.910	.066
	Six	5.65	5.80	28	0.287	.776

[a] significant at .05 level

the length quantification score variable but was rejected for grade three.

Mass Quantification Score. Significant differences in performance with respect to this variable were found to exist between the boys and girls in grades one and four. In grade one the critical "t" value of 4.045 was significant at the .001 level and in grade four the critical "t" value of 3.045 was significant at the 0.005 level, both well beyond the necessary 0.05 level of significance. The "t" values calculated for all other grades for the mass quantification score variable all yielded probabilities that were not significant at the 0.05 level. Therefore, hypothesis #2 was rejected for grades one and four but was accepted for grades two, three, five and six on the mass quantification score variable.

Time Quantification Score. Significant differences in performance with respect to this variable were found to exist between the boys and girls in grade one, the critical "t" value of 2.562 being significant at the 0.016 level. The "t" values calculated for all other grades on the time quantification score variable all yielded probabilities that were not significant at the 0.05 level. Therefore, hypothesis #2 was rejected for grade one but was accepted for grades two, three, four, five and six on the time quantification score variable.

<u>Conclusion</u>: Hypothesis #2 may be rejected for grade three for the length quantification score variable, grades one and four for the mass quantification score variable and grade one for the time quantification score variable. <u>In all four of these cases the mean quantification scores of the boys exceeded those of the girls</u>. Therefore, it may be concluded that <u>a significant difference exists between the sexes in length and time quantification abilities in grade one, mass quantification abilities in grade three, and time quantification abilities in grade four for this sample of children</u>.

<u>Hypothesis #3</u>

There is no significant difference between low, average and high I.Q. students in:

(a) Length quantification score,

(b) Mass quantification score,

(c) Time quantification score,

in each of the grades one through six.

The intent of this hypothesis was to determine if students in different I.Q. groups within each grade show significant differences in their quantification abilities, as measured by the methods used in this study. This hypothesis was tested by a Scheffé multiple comparison of means which was calculated by use of the ANOV15 IBM 360/67 computer program. As explained in Chapter 3, page 63 the 0.10 level of significance is adequate for the acceptance or rejection

of a hypothesis on the basis of the Scheffé test. Table VII provides the mean quantification scores for each I.Q. group in each grade, and a summary of the probability levels yielded by the Scheffé multiple comparison of means is to be found in Table VIII.

Length Quantification Score. Significant differences in performance with respect to this variable were found to exist between the low I.Q. group and both the average and high I.Q. groups in grades three and six. Differences in performance between the average and high groups in these two grades, however, were not significant. No significant differences were found to exist between any of the groups with respect to performance on this variable in grades one, two, four and five. See Table VIII for a complete presentation of probability levels.

Mass Quantification Score. Significant differences in performance with respect to this variable were found to exist between the low and high I.Q. groups in grades two, five and six. Differences in the mass quantification score variable between the low and average and average and high I.Q. groups in these grades were not significant other than in grade five where the 'average-high' comparison was significant at the 0.05 level. No significant differences were found between any of the groups with respect to performance for this variable in grades one, three or four. See Table VIII for a complete presentation of probability levels.

TABLE VII

MEAN QUANTIFICATION SCORES FOR EACH I.Q. GROUP PER GRADE

		Grade											
		One		Two		Three		Four		Five		Six	
Variable	I.Q. Group	Score	N	Score	N	Score	N	Score	N	Score	N	Score	N
Length	High	18.80	6	21.50	8	23.73	15	24.21	14	26.45	11	28.39	18
Quantification	Average	18.00	6	21.47	15	21.09	11	22.93	14	26.00	10	27.83	6
Score	Low	15.72	18	18.80	7	15.67	4	22.50	2	25.13	9	24.17	6
Mass	High	17.80	6	20.88	8	23.27	15	24.79	14	31.73	11	32.50	18
Quantification	Average	11.00	6	19.27	15	21.09	11	23.86	14	25.80	10	30.83	6
Score	Low	13.61	18	15.80	7	19.00	4	17.50	2	26.38	9	25.67	6
Time	High	14.80	6	20.75	8	22.40	15	25.07	14	28.64	11	30.89	18
Quantification	Average	9.17	6	17.73	15	20.27	11	23.07	14	26.60	10	28.33	6
Score	Low	9.00	18	14.20	7	14.00	4	14.00	2	25.25	9	23.83	6

TABLE VIII

SCHEFFÉ MULTIPLE COMPARISON OF MEANS OF I.Q. GROUPS PER GRADE[a]

Variable	I.Q. Groups Compared	Probability level by grade: One	Two	Three	Four	Five	Six
Length Quantification Score	High-Average	.920	.999	.109	.361	.944	.913
	High-Low	.190	.313	.001[b]	.630	.648	.012[b]
	Average-Low	.343	.255	.036[b]	.971	.834	.089[b]
Mass Quantification Score	High-Average	.173	.594	.497	.857	.020[b]	.710
	High-Low	.373	.061[b]	.352	.112	.054[b]	.008[b]
	Average-Low	.638	.190	.784	.182	.964	.128
Time Quantification Score	High-Average	.194	.587	.546	.547	.746	.571
	High-Low	.089[b]	.240	.035[b]	.017[b]	.493	.023[b]
	Average-Low	.997	.592	.155	.058[b]	.896	.322

[a]indicating significant differences between I.Q. groups in performance of quantification tasks

[b]indicates significance at the 0.10 level

Time Quantification Score. Significant differences in time quantification scores were found to exist between the low and high I.Q. groups in grades one, three, four and six for this variable. No other significant performance differences were found in these grades, other than that between the low and average groups in grade four. Grades two and five showed no significant differences between the three I.Q. groups on the time quantification score variable. See Table VIII for a complete summary of this information.

Conclusion: Significant differences in performance of the quantification tasks between I.Q. groups in each of the grades one through six are apparent in thirteen of the total fifty-four comparisons which were made. Nine of these significant differences occurred in comparisons of performance of low and high I.Q. groups. Although these significant differences between the low and high I.Q. groups appear to delineate the only major trend that is apparent throughout the grades, an increase in mean quantification scores for all parameters from low to average to high I.Q. occurred in all but two cases, the latter being between the low and average I.Q. groups in grades one and five. (See Table VIII). On the basis of the results obtained, hypothesis #3 was rejected for the high-low I.Q. groupings for length quantification score for grades three and six, for mass quantification score for grades two, five and six, and for time quantification score for grades one, three, four and

six. Hypothesis #3 can be rejected only on a random basis for the high-average and low-average I.Q. groups. Thus a distinction can generally be made with respect to performance of quantification tasks between low and high I.Q. groups only, finer distinctions being unreliable and/or meaningless. See Table VIII for this information.

Hypothesis #4

There is no significant differences between grade levels in:

(a) Length quantification score,

(b) Mass quantification score,

(c) Time quantification score,

from grade one through six.

The purpose of this hypothesis was to determine if any significant and progressive improvement in quantification abilities of students (as measured by this study) occurred from grade one through six. This hypothesis was tested by the Scheffé multiple comparison of means as calculated by by the use of the ANOV15 IBM 360/67 computer program, the 0.10 level of significance being used as a basis for the acceptance or rejection of this hypothesis. Table IX gives the Scheffé probability matrices for the multiple comparison of each of the quantification score means for grades one through six.

Length Quantification Score. In ten of a possible fifteen cases, the mean length quantification score was

TABLE IX

MEAN, VARIANCE AND STANDARD DEVIATION
OF QUANTIFICATION SCORES PER GRADE

Variance	Grade	N	Mean	Variance	Standard Deviation
Length Quantification Score	One	30	16.57	11.84	3.44
	Two	30	21.17	9.52	3.09
	Three	30	21.80	14.51	3.81
	Four	30	23.50	5.57	2.36
	Five	30	25.93	8.62	2.94
	Six	30	27.43	9.91	3.15
	Total	180	22.73	22.04	4.69
Mass Quantification Score	One	30	13.43	38.39	6.20
	Two	30	19.43	15.50	3.94
	Three	30	21.90	21.13	4.60
	Four	30	23.87	21.36	4.62
	Five	30	28.17	25.80	5.08
	Six	30	30.80	24.03	4.90
	Total	180	22.93	55.84	7.47
Time Quantification Score	One	30	9.73	29.66	5.45
	Two	30	18.40	45.83	6.77
	Three	30	20.43	29.50	5.43
	Four	30	23.40	28.59	5.35
	Five	30	26.97	34.72	5.89
	Six	30	28.97	31.76	5.64
	Total	180	21.32	71.94	8.48

found to be significantly different between the pairs of grades compared. The grade one mean score was significantly lower than the mean scores of all other elementary grades at the 0.001 level of significance. The grade two and three mean scores were significantly lower than the grade five and six mean scores again at the 0.001 level of significance and the grade four mean score was significantly lower than the grade six mean score at the 0.001 level. See Table X for this information.

Mass Quantification Score. In twelve of a possible fifteen cases the mean mass quantification score was found to be significantly different between the two grades compared. The mean scores that were significantly different for the length quantification variable were again significant beyond the 0.001 level for this variable. In addition, the grade two mean score was lower than the grade four mean score, and the mean score for grade four was lower than that of grade five, both beyond the .05 level of significance. See Table X for a complete presentation of this information.

Time Quantification Score. In eleven of a possible fifteen cases the mean time quantification score was found to be significantly different between the pairs of grades compared. The mean scores that were significantly different for the length quantification variable were again significant for this variable. The significance was at the .001 level for all comparisons except between the means of grades

TABLE X

SCHEFFÉ PROBABILITY MATRICES FOR EACH OF THE QUANTIFICATION SCORES PER GRADE

Variable	Grade	One	Two	Three	Four	Five	Six
Length Quantification Score	One	1.000	.001[a]	.001[a]	.001[a]	.001[a]	.001[a]
	Two	.001[a]	1.000	.987	.153	.001[a]	.001[a]
	Three	.001[a]	.988	1.000	.504	.001[a]	.001[a]
	Four	.001[a]	.153	.504	1.000	.120	.001[a]
	Five	.001[a]	.001[a]	.001[a]	.120	1.000	.643
	Six	.001[a]	.001[a]	.001[a]	.001[a]	.643	1.000
Mass Quantification Score	One	1.000	.001[a]	.001[a]	.001[a]	.001[a]	.001[a]
	Two	.001[a]	1.000	.588	.038[a]	.001[a]	.001[a]
	Three	.001[a]	.588	1.000	.794	.001[a]	.001[a]
	Four	.001[a]	.038[a]	.794	1.000	.049[a]	.001[a]
	Five	.001[a]	.001[a]	.001[a]	.049[a]	1.000	.514
	Six	.001[a]	.001[a]	.001[a]	.001[a]	.514	1.000
Time Quantification Score	One	1.000	.001[a]	.001[a]	.001[a]	.001[a]	.001[a]
	Two	.001[a]	1.000	.867	.052[a]	.001[a]	.001[a]
	Three	.001[a]	.867	1.000	.557	.003[a]	.001[a]
	Four	.001[a]	.052[a]	.557	1.000	.339	.019[a]
	Five	.001[a]	.001[a]	.003[a]	.339	1.000	.875
	Six	.001[a]	.001[a]	.001[a]	.019[a]	.875	1.000

[a]indicates significance at the 0.10 level

three and five, and four and six, where significance was at the 0.05 level. In addition to the significant differences already noted for this variable, the means between grades two and four were significantly different at the .05 level. See Table X for a complete presentation of the probability levels.

Conclusion: Although significant differences were not found between each of the grades on each of the three quantification variables, enough significant differences did exist to indicate a pattern of growth in quantification ability with respect to each of the parameters length, mass and time (thirty-three of a possible forty-five grade comparisons being significant). See Table X, page 80. In all but a few isolated cases this growth pattern was found to be very significant. Hypothesis #4 therefore may be rejected with respect to all variables for all comparisons between pairs of grades except between the adjacent grade pairs represented by grades two and three, three and four, and five and six. Hypothesis #4 may also be rejected with respect to the comparisons between grades two and four for the mass and time variables and between grades four and five for the mass variable.

Hypothesis #5

There is no significant interaction between grade level and I.Q. with respect to:

(a) Length quantification score,

(b) Mass quantification score,

(c) Time quantification score.

The purpose of this hypothesis was to determine if I.Q. has any differential effect on each of the criterion scores in the different grades. This hypothesis was analysed by means of a 'test for additivity' calculated by utilization of the ANOV25 IBM 360/67 computer program.

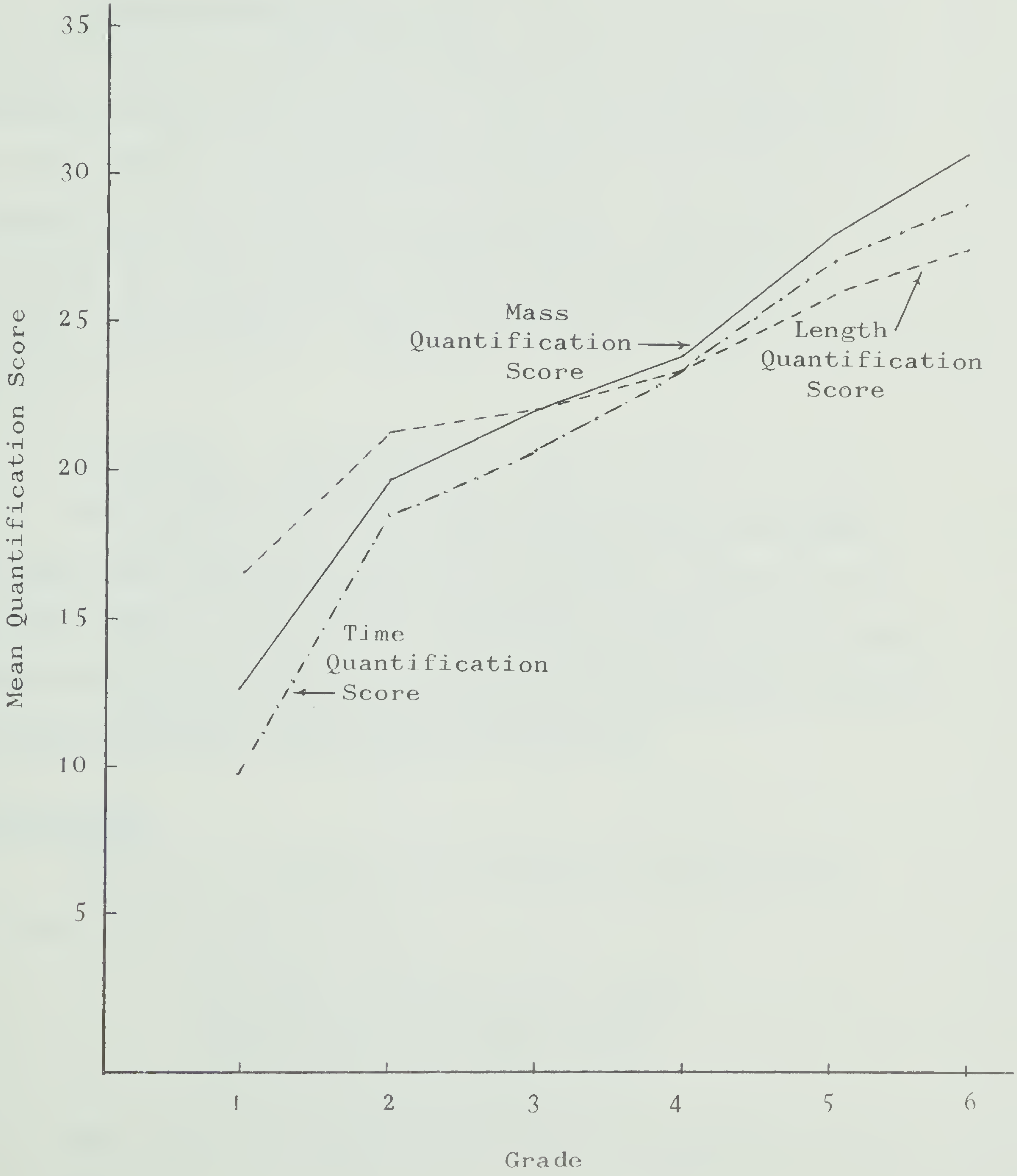
It was noted in the comparison of grade pairs that a sharp increase in quantification score occurred between grades one and two on each of the three variables. Otherwise the rate of increase in score between grades appeared to be constant as is shown in Figure 1 (for discussion of the significance of this phenomenon, see page 120).

<u>Length Quantification Score</u>. The mean length quantification score for each I.Q. group in each grade is presented in Table VII, page 74. The 'test for additivity' for this interaction yielded an F value of 1.315 which corresponds, in this case, to a level of significance of 0.339. The criterion level of significance was chosen at the 0.05 level. Therefore, the interaction is not significant and Hypothesis #5, with respect to this variable, could not be rejected. Table X, page 80, provides a summary of this information.

<u>Mass Quantification Score</u>. The mean mass quantification scores for each I.Q. group in each grade are presented in Table VII, page 74. The test for additivity for this

FIGURE 1

MEAN LENGTH, MASS AND TIME QUANTIFICATION SCORES BY GRADE



variable resulted in an F value of 1.176. Therefore, the interaction is not significant at the 0.05 level and hypothesis #5, with respect to the mass quantification score variable was not rejected. Table XI presents this information.

Time Quantification Score. The mean time quantifification scores for each I.Q. group in each grade are also presented in Table VII, page 74. The 'test for additivity' for this interaction yielded an F value of 0.561 which corresponds to a 0.843 level of significance. Therefore, hypothesis #5, with respect to the time quantification variable, was accepted. Table XI provides a summary of this information.

Conclusion: Hypothesis #5, dealing with the interaction between grade and I.Q., was accepted for the length, mass and time quantification score variables. Thus, it was concluded that no significant interaction exists between high, average and low I.Q. groups in grades one through six for the criterion variables identified in this study.

Hypothesis #6

There is no significant interaction between grade level and sex with respect to:

(a) Length quantification score,

(b) Mass quantification score,

(c) Time quantification score.

The intent of hypothesis #6 was to determine if sex

TABLE XI

INTERACTION BETWEEN GRADE AND I.Q. WITH RESPECT TO QUANTIFICATION SCORES

Variable	Source of Variance	Sum of Squares	D.F.	Mean Squares	F	Prob.
Length Quanti-fication Score	Interaction	.966875	10	.966875	1.135	.339
	Error	.133694	157	.851552		
Mass Quanti-fication Score	Interaction	.245062	10	.245062	1.176	.311
	Error	.327262	157	.208447		
Time Quanti-fication Score	Interaction	.164187	10	.164187	0.561	.843
	Error	.459306	157	.292552		

has any differential effect on each of the criterion scores in the different grades. This hypothesis was analysed by means of the 'test for additivity' calculated by the ANOV25 IBM 360/67 computer program.

Length Quantification Score. The mean length quantification scores for boys and girls in each grade are presented in Table V, page 69. The 'test for additivity' for this variable yielded an F value of 1.383 which results in a level of significance of 0.233. Therefore, there is no significant interaction between sex and grade on the length quantification score variable and hypothesis #6, with respect to this variable, was accepted. Table XII, page 87, summarizes this information.

Mass Quantification Score. The mean mass quantification scores for boys and girls in each grade are also presented in Table V, page 69. The 'test for additivity' on this variable resulted in an F value of 3.160. This F value yields a probability of 0.009, a highly significant interaction. Therefore, hypothesis #6, with respect to the mass quantification score variable was rejected. Table XII, page 87, provides a summary of this information.

Time Quantification Score. The mean time quantification scores for boys and girls in each grade are given in Table V, page 69. The 'test for additivity' for this variable yielded an F value of 0.605, which corresponds to

TABLE XII

INTERACTION BETWEEN GRADE AND SEX WITH RESPECT TO QUANTIFICATION SCORES

Variable	Source of Variance	Sum of Squares	D.F.	Mean Squares	F	Prob.
Length Quantification Score	Interaction	.666250	5	.133250	1.383	.233
	Error	.161912	168	.963765		
Mass Quantification Score	Interaction	.333187	5	.666375	3.160	.009[a]
	Error	.354262	168	.210871		
Time Quantification Score	Interaction	.982500	5	.196500	.605	.697
	Error	.546075	168	.325045		

[a]indicates significance at .05 level

a probability of 0.697. Therefore, there is no significant interaction between grade and sex on the time quantification score variable, and hypothesis #6, with respect to this variable, was accepted. This information is also given in Table XIII.

Conclusion: Hypothesis #6, dealing with the interaction between grade and sex, was accepted with respect to the mass quantification score variable. Further investigation of this interaction showed that the results were due mainly to the extremely high scores obtained by the boys as compared to the girls in grades one and four. This interaction is graphically illustrated in Figure 2.

The significance and implications of these conclusions is discussed in Chapter 5.

DESCRIPTION OF PERFORMANCE

The average performance for each of the elementary grades on the three quantification subtests is shown in Table IX, page . The table indicates there is a rapid increase in mean quantification score between grades one and two, and a gradual and continuous increase thereafter, at least until grade six. The average performance of the pupils in each grade for each of the scored questions in each subtest is shown in Tables XIII through XV. (See also Appendix I for frequency matrices for each question and grade.) These tables indicate the following:

Questions two through nine, which were related to an

FIGURE 2

INTERACTION BETWEEN GRADE AND SEX

ON MASS QUANTIFICATION SCORE CRITERION

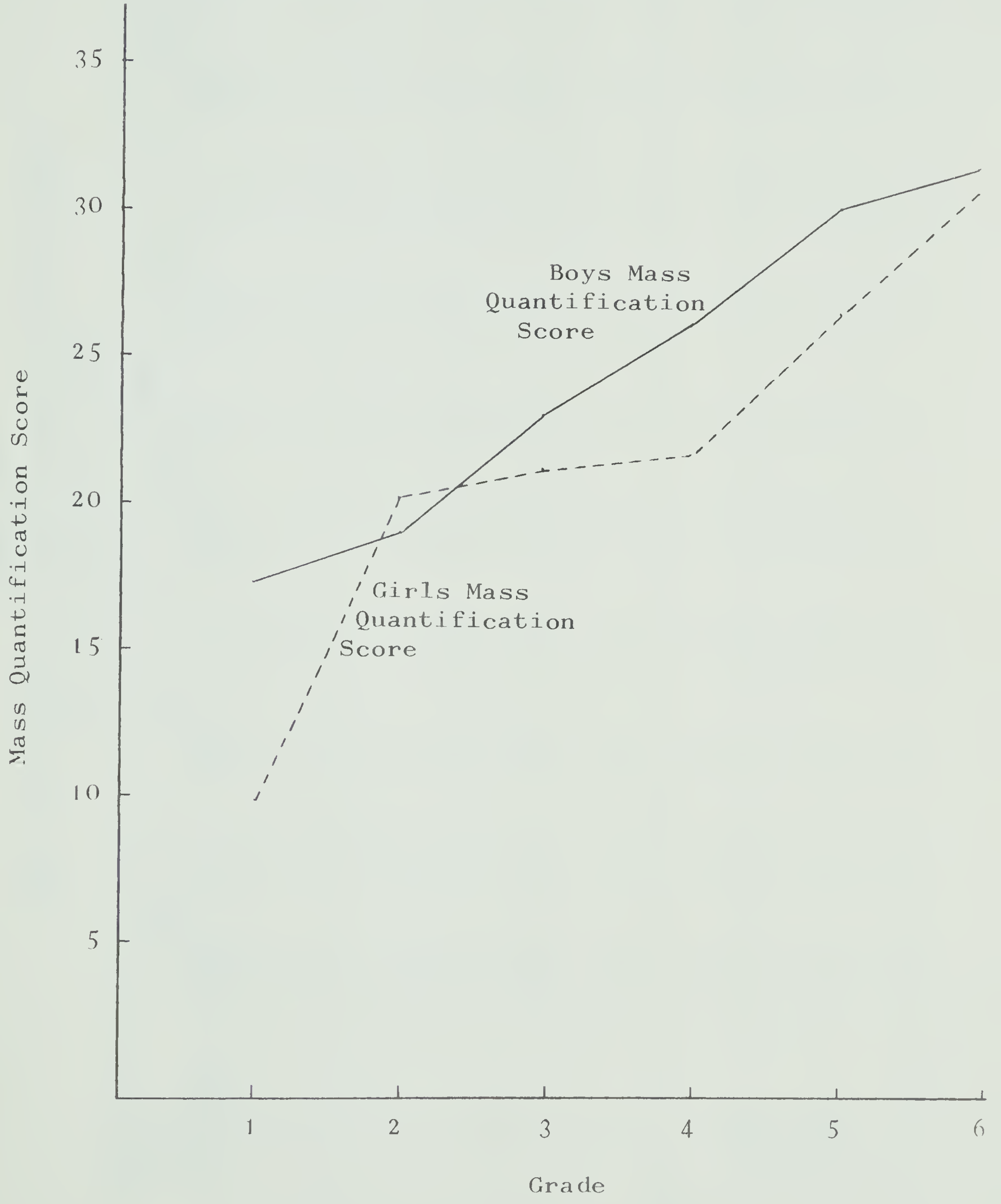


TABLE XIII

MEAN AND VARIANCE OF LENGTH QUANTIFICATION SCORES FOR EACH QUESTION BY GRADE

		Grade											
	Total Score	One		Two		Three		Four		Five		Six	
Question	Possible	Mean	Var.	Mean	Var.	Mean	Var.	Mean	Var.	Mean	Var.	Mean	Var.
Two	3	3.00	3.00	2.97	0.03	2.97	0.03	2.97	0.03	2.93	0.13	2.93	0.06
Three	3	0.20	0.43	0.20	0.36	0.43	0.78	0.70	0.94	1.27	1.20	1.93	0.53
Five	3	2.17	0.54	2.33	0.22	2.30	0.28	2.30	0.21	2.40	0.24	2.40	0.24
Six	1	0.30	0.41	0.53	0.25	0.80	0.16	0.60	0.24	0.63	0.23	0.80	0.16
Eight	3	1.67	1.89	2.70	0.41	2.77	0.45	2.97	0.03	2.97	0.03	2.90	0.09
Nine	3	1.67	0.56	2.50	0.32	2.57	0.25	2.57	0.25	2.63	0.23	2.43	0.25
Ten and Thirteen	6	3.93	0.93	4.70	0.41	4.33	0.69	4.83	0.27	4.87	0.25	4.87	0.25
Twelve and Fifteen	9	1.67	2.42	2.90	3.62	3.30	3.48	4.07	2.53	5.23	2.71	5.53	2.18
Sixteen	No Max.	0.57	0.45	0.33	0.29	0.23	0.25	0.27	0.20	0.47	0.45	0.60	0.71
Seventeen	No Max.	0.40	0.31	0.97	0.50	0.87	0.52	1.10	0.49	1.17	0.61	1.53	0.58
Eighteen	2	1.00	0.27	1.03	0.17	1.23	0.18	1.13	0.18	1.37	0.23	1.50	0.25

TABLE XIV

MEAN AND VARIANCE OF MASS QUANTIFICATION SCORES

FOR EACH QUESTION BY GRADE

Question	Total Score Possible	Grade: One		Two		Three		Four		Five		Six	
		Mean	Var.	Mean	Var.	Mean	Var.	Mean	Var.	Mean	Var.	Mean	Var.
Two	3	2.03	1.17	2.60	0.64	2.63	0.70	2.63	0.56	2.77	0.38	2.93	0.13
Three	3	0.10	0.09	0.83	1.74	1.43	1.45	1.70	0.67	2.13	0.65	2.27	0.46
Five	3	1.47	0.52	1.77	0.18	1.77	0.58	1.80	0.36	1.83	0.41	1.97	0.17
Six	1	0.13	0.11	0.07	0.06	0.17	0.14	0.23	0.18	0.37	0.23	0.40	0.24
Eight	3	1.63	1.90	2.50	0.72	2.93	0.06	2.83	0.34	3.00	0.00	2.97	0.03
Nine	3	1.50	1.05	2.27	0.66	2.40	0.57	2.33	0.62	2.30	0.68	2.57	0.51
Ten and Thirteen	5	2.47	1.12	2.93	0.80	3.07	0.46	3.33	0.62	3.83	0.27	3.73	0.40
Twelve and Fifteen	16	2.33	2.56	3.67	4.02	4.33	4.16	5.80	6.09	8.30	9.54	9.50	8.38
Sixteen	No Max.	0.47	0.45	0.93	0.53	1.10	1.22	0.80	0.36	1.13	0.85	1.53	1.25
Seventeen	No Max.	0.83	0.25	0.77	0.45	0.93	0.40	1.13	0.52	1.13	0.45	1.50	0.72
Eighteen	2	1.20	0.21	1.10	0.09	1.13	0.18	1.27	0.26	1.37	0.23	1.43	0.25

TABLE XV

MEAN AND VARIANCE OF TIME QUANTIFICATION SCORES

FOR EACH QUESTION BY GRADE

Question	Total Score Possible	Grade											
		One		Two		Three		Four		Five		Six	
		Mean	Var.	Mean	Var.	Mean	Var.	Mean	Var.	Mean	Var.	Mean	Var.
Two	3	1.20	1.96	2.30	1.41	2.17	1.41	2.50	1.25	2.47	1.12	2.70	0.61
Three	3	0.00	0.00	0.17	0.41	0.10	0.09	0.50	0.85	0.63	0.90	0.93	1.20
Five	3	1.03	1.03	1.67	1.22	1.47	0.78	1.87	1.05	2.07	0.73	1.97	1.17
Six	1	0.03	0.03	0.03	0.03	0.30	0.21	0.40	0.51	0.47	0.25	0.47	0.32
Eight	3	0.60	1.11	1.47	1.72	2.07	1.60	2.13	1.52	2.77	0.58	2.80	0.23
Nine	3	1.33	1.29	1.97	0.77	2.67	0.29	2.37	0.63	2.43	0.45	2.67	0.22
Ten and Thirteen	4	2.43	1.51	3.03	0.57	2.90	0.56	3.00	0.33	3.23	0.31	3.30	0.68
Twelve and Fifteen	12	1.50	3.45	4.57	7.98	5.27	6.40	6.90	6.56	8.17	5.47	9.27	6.93
Sixteen	No Max.	0.37	0.30	0.67	0.56	0.63	0.50	0.70	0.34	1.13	1.05	0.93	0.80
Seventeen	No Max.	0.23	0.18	0.87	0.32	0.80	0.49	1.00	0.33	1.17	0.47	1.53	0.78
Eighteen	2	0.60	0.31	0.77	0.18	0.93	0.20	0.93	0.13	1.17	0.21	1.07	0.20

understanding of the basis of measurement, were scored using the 3,2,1,0 scale (Method 1, page 53). The following comments deal with specific points relating to certain of these questions:

Question 2

Is there any difference? What?

It was found that all six grades were aware that stimulus test objects in each of the groups differed with respect to the basic property focussed upon (length, mass/weight, or time duration). The mean score for this question essentially remained constant through the grades for length, most students volunteering the expected response. For mass and for time, however, a gradual, continuous increase in score was apparent.

Question 3

What word tells us the way these things are different?

This question was generally found to be much more difficult to answer than question 2 for students in all grades. Students encounter much more difficulty in naming the variant property. Ability in this improved through the grades, but it was not until grade five that more than 50% of the subjects were able to name the variant property as 'length' in the first subtest (twenty of thirty subjects doing so in grade five).

The mass/weight variable in the second subtest was named as such by more than 50% of the subjects starting in

grade three. However, none of the one hundred and eighty subjects named the variant property as 'mass', 'weight' being the common response.

The time duration variable was the most difficult property of the three to name. In none of the grades did 50% of the subjects name it correctly but, in grade six, fourteen of thirty subjects named it correctly. The grade six mean score of 0.93 indicates, however, that much prompting was necessary in order to elicit the correct name of the variant property.

<u>Question 5</u>

Now arrange them!

It was found that children in all grades could order the objects according to increasing magnitude, in both the length and the time subtests, with nearly the same degree of proficiency. The mean scores on the length subtest varied from 2.17 (grade one) to 2.40 (grade six) out of a possible 3.00 points, and the mean scores on the mass/weight subtest varied from 1.47 to 1.97 points, again out of a possible total of 3.00. The ordering of the sounds according to increasing magnitude in subtest three was found to be a more difficult task for the grade one students than it was for the students in the other grades, a mean score of 1.03 being obtained for grade one, increasing to 1.67 for grade two, and to 1.97 for grade six. The grade one subjects found this question most difficult with respect to the time subtest, the

mass/weight subtest coming next in difficulty, the length subtest being the easiest of the three. Each of the other grades were equally proficient in the length subtest with respect to this question.

Question 6

Can you guess the size of this ______________?

It was found that children in all of the grades experienced difficulty in estimating the magnitude of a selected stimulus test object during the course of each of the three subtests, the mean score varying from 0.30 (grade one) to 0.80 points (grade six) out of a possible 1 point for the seventeen ounce block on the mass/weight subtest and from 0.03 points (grade one) to 0.47 points (grade six) out of a possible 1 point for the five second sound duration on the time subtest. Generally, the estimations given were much greater in magnitude than the actual value, especially for mass/weight and time. It would appear that all six grades require practice in estimating.

Question 8

How could you find out the exact size of ________?

It was found that most students realized that it was necessary to measure the stimulus test objects in order to make an accurate determination of the differences between them, one hundred sixty-seven students doing so for the length subtest, one hundred sixty-five for the mass/weight subtest, and one hundred thirty-one for the time subtest.

The mean scores on the length subtest for this question for the primary grades increased from 1.67 points in grade one to 2.70 points in grades two and three. Mean scores for grades four to six, however, remained constant at 2.9 points out of a possible 3.00 points.

Mean scores on the mass subtest increased from 1.63 points in grade one to 9.93 points in grade three. Thereafter mean scores for each grade remained relatively constant. Mean scores on the time subtest showed a steady increase from grade one to five, varying from 0.60 points to 2.77 points. After grade five, a levelling off in mean score is apparent. Grade one subjects do not appear fully to have mastered the concept of length measurement, but all grades thereafter seem competent in this respect. Students in grades one and two do not appear to have mastered the concepts of mass/weight and time fully, although grade two subjects show greater ability than those from grade one. The concept of time appears to be particularly de i ient in the first two grades. Beyond grade two, however, mastery of this concept is apparent, at least 2.0 points of a possible 3.0 being obtained.

<u>Question 9</u>

What would you use to measure the ______________?

It was found that a majority of students from each grade knew of a measuring instrument that could be used to carry out the appropriate measurement for each of the sub-

tests. Of the total sample, one hundred seventy-seven knew of an appropriate instrument for measuring mass/weight and one hundred sixty-five subjects knew of an appropriate instrument for the measurement of time duration. In all three subtests, for all grades other than grades one and two on the mass subtest, and grades one to four on the time subtest, a slightly lower mean score was obtained on this question than on the previous question which centered upon the need for measurement for the accurate determination of differences. This circumstance, of course, was to be expected, but was not encountered on the mass subtest for the first two grades and on the time subtest for the first four grades. For example, in grade one, on the time subtest, eight students realized that time variations could be accurately measured, but twenty students knew the name of an appropriate measuring instrument for measuring time. Similar results were obtained in the other cases, more students knowing the name of an instrument that could be used to measure the parameter than knowing that measurement could be used to compare objects accurately for possible differences. One possible explanation of this phenomenon is the everyday home use of clocks and scales. By the time children reach school age they know superficially what clocks and scales are used for. However, the concept of comparative use may not yet have developed. It would appear then that the concept of comparison needs to be introduced and/or strengthened during the course of science instruction in the elementary school.

Questions 10 and 13

> Which one of the things over there would you like to use to make the measurement?
>
> Are there any other things on the table which you could use to make the same kind of measurement?

All one hundred eighty subjects recognized at least two appropriate measuring instruments for measuring length, one hundred seventy-eight subjects recognized at least one appropriate measuring instrument for measuring mass/weight, and at least one hundred seventy-five subjects recognized one appropriate measuring instrument for measuring time duration. Only six subjects recognized all six instruments capable of measuring length, calipers being the instrument omitted by one hundred sixty-six subjects. Seven students recognized all five instruments capable of measuring mass or weight, with an additional sixty-seven subjects omitting only the elastic band. Forty-five subjects recognized all four instruments for measuring time (See Appendix , page , for a summary of the above information). Mean scores with respect to this question on the length subtest ranged from 3.93 points (grade one) to 4.87 points (grade five) out of a possible 6.0 points, 1 point being given for identification of each instrument. Mean scores on the mass/weight subtest ranged from 2.47 points (grade one) to 3.73 points (grade six) out of a possible 5.0 points. Mean scores on the time subtest ranged from 2.43 points (grade one) to 3.30 points (grade six) out of a possible 4.0 points. It appears that

skill in recognizing instruments appropriate for the measurement of each property is satisfactory, except in isolated cases. See page for further discussion of this matter.

Questions 12 and 15

> Now, make your measurement with it!
>
> Now, I'd like you to use each of these other things which you've chosen to measure the _______ which we have here. First, I'd like you to use this and this!

These questions were scored using the 3,2,1,0 scale of Method 1, as described on page

Of the one hundred eighty subjects in the total sample, one hundred fifty-nine obtained at least 1.0 point on the length subtest with respect to these questions. Only four subjects scored the maximum of 9.0 points, owing to the omission of 'calipers' in most cases. Sixty-two subjects were able to use both an instrument larger and an instrument smaller than the object being measured. Generally, however, children in the primary grades could not use an instrument that was smaller than the object. The mean scores for the length subtest ranged from 1.67 points in grade one to 5.53 points in grade six. It appears, in general, that weakness in ability in measuring exists, particularly in grades one through three.

Of the one hundred eighty students in the total sample, one hundred sixty-nine obtained at least 1.0 point on the mass/weight subtest. Although none of the students obtained the maximum of 1(.0 points on these questions, nine scored 13.0

points. The mean scores for the mass/weight subtest ranged from 2.33 points in grade one to 9.50 points in grade six, a progressive and significant increase being observed through the grades. It appears that weakness in ability to measure mass/weight exists, particularly in the first four grades.

Of the one hundred eighty students in the total sample, one hundred sixty obtained at least 1.0 point on the time subtest with respect to these questions. Seventeen students, mainly from grades five and six, scored the maximum possible, 12. Mean scores ranged from 1.50 points in grade one to 9.27 points in grade six, a progressive and significant increase being observed through the grades. It appears that a great deal of weakness exists in the first four grades in ability to measure time duration, this deficiency not being apparent thereafter.

Question 16

> Are there any other things that you know of which are not on this table which you could use to measure these __________?

This question, which involved the naming or describing of other instruments that could be utilized in quantification tasks similar to those presented in the study, was poorly answered by all six grades on all three subtests, only sixty-one students knowing of any additional instruments that could be used to measure length, the maximum number named by any one student being three. 1 point was given for each correct response with no maximum limit set. The mean scores for this question for the length subtest ranged from 0.23 points (grade

three) to 0.06 points (grade six). The mean score did not increase progressively through the grades for this parameter, the mean score for grade one students being 0.57, for grade two students 0.33, and for grade three students 0.23. A possible explanation for this might be that students in the first two grades are generally encouraged to use "unique" measuring instruments (For example, cardboard strips, body parts, etc.) rather than instruments of general applicability which have standardized scales (rulers, tape measures, etc.). The "unique" instruments, drawn from the student's immediate past experience, are readily recalled. However, students in grades three to six, who commonly use standard instruments for measuring length, generally disregard those instruments which do not bear standard scales.

For the mass quantification subtest, only one hundred twenty-one students mentioned one or more additional instruments which could be used to measure mass/weight, the most common response encountered being 'bathroom scale'. The maximum number of additional instruments mentioned during this subtest was five. Mean scores for this question for the mass subtest ranged from 0.47 (grade one) to 1.53 (grade six), a progressive increase from grade to grade occurring, with the exception of grade four, the exception probably being due to sample bias.

For the time subtest, only one hundred two students mentioned an additional instrument capable of measuring time, the most common response being 'wristwatch', the maximum

number of additional instruments given for measuring time being four. Mean scores for question 16 for this subtest ranged from 0.37 (grade one) to 1.13 (grade five) in a continuous and progressive manner. The drop in mean score in grade six is again possibly attributable to sample bias.

It is apparent from the results obtained for this question that instruments familiar to the students were usually chosen and used for measuring the parameters associated with the tasks presented during the interview. For this reason, the low scores obtained by the students for this question do not necessarily indicate a deficiency which requires remedial action. However, enrichment in this area may be provided in the form of discovery and/or research in order to improve the student's perception and versatility.

Question 17

(a) How could you make sure that your measurement is right?
(b) How could you check your measurement?

Question 17, concerning the description of procedures for determining the accuracy of a measurement, was attempted by the majority of the students for each parameter. As in question 16, 1 point was given for each correct response, with no maximum limit being set for the total number of responses.

For the length subtest, one hundred thirty-four students described at least one correct procedure for determining accuracy, the maximum number of methods described by any one

student being four. With the exception of grade one, more than 75% of the students in each grade knew of at least one method. Mean scores for this question for the length subtest ranged from 0.40 (grade one) to 1.53 (grade six) in a continuous and progressive manner, other than for grade two, the anomalous result in this case probably being due to chance or to sample bias.

For the mass/weight subtest, one hundred thirty-six students described at least one correct method of determining accuracy of measurement, the maximum for any one student being three. Grades three through six yielded at least a 75% student success rate for at least one of the appropriate procedures. Mean scores ranged from 0.77 (grade two) to 1.50 (grade six) in a gradual and progressive manner. The 0.83 mean score for grade one students on this question is attributed to sample bias and is comparable in value to the mean score obtained for grade two.

For the time subtest, one hundred twenty-eight students described a correct method of determining accuracy, while seven described three methods, the maximum number mentioned. With the exception of grades one and three, more than 75% of the students in each grade were aware of at least one method. Mean scores for the time subtest ranged from 0.23 (grade one) to 1.53 (grade six). The increase through the grades was progressive, except between grades two and three, where a drop of .07 was noted, again probably attributable to sample bias.

The results for question 17 indicate that students in grades one through three do not have adequate knowledge of the appropriate procedures for checking the accuracy of their work in an independent laboratory-based science program. As quantification skill is expected to be developed during these grades, methods of determing and improving the accuracy of one's own laboratory measurement work should be stressed.

Question 18

> What other things that you know of can be measured in the same way?

This question, which involved the naming and/or description of other objects or situations in which the three areas of measurement could be employed, was scored two points for a generalized answer and one for a specific answer. For all three parameters, a majority of the students gave specific answers (one hundred twenty-eight of one hundred seventy-three for the length subtest, one hundred thirty of one hundred seventy-two for the mass subtest, and one hundred thirty-six of one hundred fifty for the time subtest). The mean scores on the length subtest for this question rose progressively from 1.00 (grade one) to 1.50 (grade six). The progression was interrupted only by the grade three mean score, which was 0.10 greater than that for grade four, a factor possibly attributable to chance or to sample bias.

The results of question 18 show that children generally express themselves in concrete terms during the elementary grades, a conclusion already drawn by many other researchers. Although this situation probably needs no correction and may

not, in fact, be modifiable, the higher grades of elementary school should perhaps be increasingly subjected to the use of general terms in order to prepare the students for, and perhaps stimulate the advent, of the formal operations level of intellectual development.

The data on which the above discussion is based, is to be found in Tables XIII to XV, pages 90 to 92 , additional data being given in Appendix I , page 180.

USE OF THE MEASURING INSTRUMENTS PROVIDED

Fifteen measuring instruments were available for use in this study, six for the length quantification subtest, five for the mass quantification subtest and four for the time quantification subtest. The number and order of presentation of the measuring instruments used for each of the three subtests was determined by the student being interviewed. Table XVI shows the frequency of choice of each measuring instrument. These tables illustrate certain features of each subtest as discussed below:

Length Quantification Subtest

The frequency pattern on the 'total frequency' table (Table XVI) shows that foot rulers were chosen a total of one hundred sixty-eight times, closely followed by meter sticks and 'sewing' measuring tapes, each with frequencies of one hundred sixty-seven times. The six inch ruler was chosen a total of one hundred fifty-eight times, while the retractable steel tape was chosen one hundred fifty times. Calipers were

TABLE XVI

FREQUENCY OF CHOICE OF MEASURING INSTRUMENTS BY GRADE AND SEX

Instrument	GRADE						Boys	Girls	Total
	One	Two	Three	Four	Five	Six			
Meter Stick	24	29	27	28	29	30	84	83	176
Foot Ruler	21	29	28	30	30	30	82	86	168
Six Inch Ruler	21	25	25	28	30	29	82	76	158
Retractable Steel Tape	19	27	22	27	28	27	80	70	150
Sewing Measuring Tape	25	30	26	30	27	29	84	83	167
Calipers	1	2	1	1	2	1	5	3	8
Spring Bal.	10	9	9	15	21	27	53	38	91
Triple Beam Balance	22	28	29	26	30	26	81	80	161
Pan Balance	24	27	24	28	29	29	80	81	161
Weigh Scale	20	25	27	28	29	28	85	72	157
Elastic	0	1	1	3	2	3	7	3	10
Clock	23	30	28	26	30	29	86	80	166
Stopwatch	22	28	29	27	28	29	84	79	163
Metronome	5	8	6	4	8	16	25	22	47
Timer	21	26	25	29	29	24	82	73	154

chosen only eight times. The frequency pattern on the 'first choice frequency' table (Table XVII) indicates a similar general pattern with the foot ruler being chosen sixty-three times, followed by the meter stick (fifty-two times), the 'sewing' tape measure (thirty times), the retractable steel tape (twenty-two times), the six inch ruler (ten times), and the calipers (zero times). Grades one, three, five and six students chose the foot ruler more times than any other instrument. However, grade two students chose the meter stick most often. Grade four students showed no preference between foot ruler and meter stick.

No clearcut preference by sex was indicated with respect to measuring instruments used for measuring length, other than for the retractable steel tape, which was chosen by boys ten more times than by girls.

The results indicate that the foot ruler was preferred overall, followed by the meter stick and 'sewing' tape. These instruments appear to be the most familiar to the student in the pursuit of everyday activities at home and at school. The six inch ruler may have been avoided because of its apparent lack of usefulness in measuring objects of greater size. There appears to be a significant lack of understanding among students with respect to the potential use of calipers as a device for measuring length. The only other major pattern noted through the grades is the progressive increase in first choice of foot ruler with increase of grade, a circumstance which is probably an indication of

TABLE XVII

FREQUENCY OF FIRST CHOICE OF MEASURING INSTRUMENT ABILITY TO MAKE PROPER USE OF INSTRUMENT CHOSEN BY GRADE AND SEX

	GRADE								
Instrument	One	Two	Three	Four	Five	Six	Boys	Girls	Total
Meter Stick	6	10	7	11	8	10	27	25	52
Foot Ruler	8	7	9	11	12	16	30	33	63
Six Inch Ruler	3	5	1	1	0	0	7	3	10
Retractable Steel Tape	3	5	6	2	5	1	12	10	22
Sewing Measuring Tape	6	3	8	5	5	3	17	13	30
Calipers	0	0	0	0	0	0	0	0	0
Spring Bal.	4	0	0	1	6	7	10	8	18
Triple Beam Balance	10	8	6	5	7	3	18	21	39
Pan Balance	7	11	8	13	6	10	32	23	55
Postal Scale	5	8	16	10	11	10	28	32	60
Elastic	0	0	0	0	0	0	0	0	0
Clock	10	18	12	11	9	11	29	42	71
Stopwatch	5	5	13	14	17	19	41	32	73
Metronome	0	2	0	2	0	0	2	2	4
Timer	3	4	2	3	5	4	12	9	21

familiarity due to its ever increasing use by students as they progress through school. A possible reason for the preference shown by boys for the retractable steel tape might be its association with carpentry, a masculine endeavor. By the same token, however, the 'sewing' measuring tape was not particularly preferred by girls compared with boys, so the line of reasoning just presented may not be particularly valid.

Mass Quantification Subtest

The frequency pattern on the 'total frequency' table (Table XVI) shows that pan balances and triple beam balances were chosen a total of one hundred sixty-one times each, making them the most used instruments during the mass quantification subtest. These two instruments were closely followed in frequency of use by the postal scale, which was chosen by students a total of one hundred fifty-seven times. The spring balance was chosen a total of ninty-one times, being chosen by 50% or more of the students only in grades four through six. The elastic band was chosen ten times. The frequency pattern showed a slight shift in the 'first choice' frequency table (Table XVII). It was found that the most used instrument was the 'postal scale', which was chosen sixty times, followed by the pan balance (fifty-five times), the triple beam balance (thirty-nine times), the spring balance (eighteen times) and the elastic band (zero times). Surprisingly, grade one students preferred the triple beam

balance. However, grades two and four students chose the pan balance, and grades three and five students the postal scale. Grade six students chose both the pan balance and the postal scale ten times.

The results on the 'total frequency' table indicate that two instruments were chosen by boys more times than by girls, the spring balance being chosen fifty-three times by boys and only thirty-eight times by girls, and the postal scale being chosen eighty-five times by boys and only seventy-two times by girls. The results of the first choice frequency table indicate that boys chose the pan balance ten more times than girls did.

The results of measuring instrument choice for the mass quantification subtest indicate that the postal scale is preferred overall, closely followed by the pan balance. These instruments closely approximate two things in the children's environment, the former resembling a common 'bathroom scale' and the latter resembling a playground 'see-saw'. This might be the possible reason for the display of these preferences. Choice of the triple beam balance shows a definite pattern of preference, as it was chosen fewer times in each succeeding grade after grade one. This might be an indication of its lack of use in the elementary school, children from grade one possibly choosing it mainly because of its 'fancy mechanical' appearance, students from the latter grades not choosing it because of their acknowledged unfamiliarity with it. No other straightforward pattern is

indicated through the grades. It appears, however, that students from the upper elementary grades are more aware of the use of a spring balance than students in the primary grades. Generally, none of the six grades are aware of the potential use of an elastic band for measuring weight, probably because of their lack of previous experience with this uncommon instrument. The avoidance of the elastic band may also indicate an intrinsic 'lack of insight' or a lack of exposure to improvisation techniques in experimentation. Although boys showed more preference for the spring balance and the postal scale in total choices and for the pan balance in first choices, no reason for this circumstance can be advanced.

Time Quantification Subtest

The frequency pattern on the 'total frequency' table (Table XVI) shows that the clock was chosen a total of one hundred sixty-six times, followed closely by the stopwatch, which was chosen a total of one hundred sixty-three times. The timer was chosen one hundred fifty-four times and the metronome forty-seven times. The frequency pattern on the 'first choice frequency' table (Table XVII) indicates a slight shift in measuring instrument preference. The stopwatch was the most used instrument on a first choice basis with seventy-three students using it first, followed by the clock, with seventy-one student choices. The timer was chosen first by twenty-one students, and the metronome by four students.

Grade one and two students chose the clock a significantly greater number of times than the other instruments available for measuring time.

Grade three students showed little preference with respect to the clock or stopwatch as a first choice. Students in grades four through six chose the stopwatch more often than they chose the clock, metronome or timer. The metronome was chosen only sporadically while the timer was chosen approximately the same number of times throughout the grades.

The results shown on the total frequency table indicate that, on the basis of sex, no significant differences in choice were made. The results illustrated by the first choice frequency table, however, indicate that boys chose the stopwatch nine times more than girls did, while the girls chose the clock thirteen times more than the boys did.

The results of measuring instrument choice for the time quantification subtest indicate that the clock and stopwatch are preferred to the same degree for measuring time duration. However, the clock is preferred in the first two grades while the stopwatch is preferred in grades four through six. The timer, preferred almost to the same extent throughout the grades, is the third choice of most students. However, the metronome, a rather 'obscure' instrument, was preferred in relatively few cases, and was a very infrequent fourth choice. A possible reason for the preference of the first two grades for the electric clock might be its familiarity, electric clocks being a common feature of both the home and

school environments. The shift in preference after grade three might well be symptomatic of the developing child's increasing realization that stopwatches measure time duration more precisely than an ordinary clock does. Timers and metronomes were chosen in the order indicated probably because of their general unfamiliarity to the child. No apparent reason seems to exist for the greater preference shown by boys over girls for choice of the timer. A possible reason for the more frequent choice by boys of stopwatches might be the greater emphasis placed on organized sport for boys, a situation in which stopwatches are commonly used. Similarly, the reason girls may have chosen clocks more times than boys might be the strong association of such devices with domestic situations (cooking, baby feeding, etc.).

SUMMARY OF RESULTS

Hypothesis #1 examined the relationships existing between length, mass and time quantification scores and the relationships existing between quantification score and other variables. It was found that significant relationships existed between all three quantification scores and between each quantification score and grade, age, general intelligence, verbal ability, spatial relations ability, perceptual speed ability, previous experience, and teacher's perception of the student's ability in science. Significant relationships were also found to exist between mass quantification score and the sex variable, and between the time quantification score and the reasoning ability variable.

Hypothesis #2 compared boys scores with those of girls in each of the grades one to six. Only in the cases of grade three for length quantification score, grades one and four for mass quantification score, and grade one for the time quantification score was a significant difference between the sexes noted, boys demonstrating superior performance in all four cases.

Hypothesis #3 compared the scores obtained by each of the three defined I.Q. groups in each of the grades one through six. Significant differences occurred between the high and low I.Q. groups for length quantification score for grades three and six, and for mass quantification score for grades one, three, four and six. Fewer significant differences were found between the high and average and the average and low I.Q. groups.

Hypothes #4 compared the quantification score for each grade with the scores for each of the other grades, a significant growth pattern from grade one through six emerging. The differences among the mean scores of the grades was very significant in the majority of cases.

Hypothesis #5 examined the possibility of the existence of interaction between the variables 'I.Q.' and 'grade level'. It was found that no significant interaction existed between high, average, and low I.Q. groups in grades one through six for the three quantification score variables of this study.

Hypothesis #6 also examined the possibility of interaction between sex and grade for the three quantification

scores. This hypothesis was rejected for the length and time quantification score variables, but was accepted for the mass quantification score variable. Significant interaction existed between grade and sex for this latter variable.

Students made use of fifteen different measuring instruments in this study, six for length, five for mass/weight and four for time, and would probably have made use of other instruments had they been made available. The results indicated that the foot ruler and the meter stick were the most popular choices for measuring length, the clock and stopwatch the most popular for time, and the pan balance and postal scale being the most popular for mass/weight, previous experience being the single best predictor of preference. Students in grades one through three indicated no single instrument preference on the length subtest. However, they preferred the postal scale on the mass subtest and the clock on the time subtest. The students in grades four through six preferred the foot ruler for measuring length, the postal scale for measuring mass/weight, and the stopwatch for measuring time. Boys chose the retractable steel measuring tape, the spring balance, the postal scale, and the timer more often than the girls did. Boys also preferred foot rulers for measuring length, pan balances for measuring mass/weight, and stopwatches for measuring time. Girls also preferred foot rulers for measuring length, but their preference for using postal scales for mass/weight measurement and clocks for time measurement indicates that the sexes do not have identical taste in choice of measuring instruments.

Chapter 5

SUMMARY, CONCLUSIONS, IMPLICATIONS AND SUGGESTIONS FOR FURTHER RESEARCH

SUMMARY

The main purpose of this study was to determine the quantification abilities of children in grades one through six. The development of these abilities through the first six grades was examined in order to discover significant predictors of quantification ability, to determine some of the difficulties children experience in carrying out tasks involving quantification, and to identify and compare the procedures and preferences of the grades with respect to choice of measuring instruments.

This study was carried out on a sample of one hundred and eighty elementary school students, sixty from each of the Edmonton Public, the Edmonton Separate, and the County of Strathcona school systems. The sample was composed of thirty randomly selected students, stratified by sex, from each of the grades one through six.

The I.Q. level for each child was assigned on the basis of his I.Q. score on the S.R.A. Primary Mental Abilities Test administered during the course of the investigation. The five subtests which are stated to measure five primary mental abilities within this particular measure of general intelligence were used in order to indicate which mental

abilities so defined, contributed most to quantification skill.

Each student in the sample was tested individually for quantification ability by the investigator, in a private room in the school which the child attended. Each student was presented with a group of stimulus test objects, together with a series of related questions and a set of measuring instruments. The child was evaluated on the basis of the answers given to the questions, which were presented orally, and on the basis of the accuracy of the measurements carried out as well as on the total number of appropriate measuring instruments used.

The data thus obtained were subjected to an analysis of variance calculated by means of the ANOV1Ø, 15 and 25 IBM 360/67 computer program, all programs being provided by the Division of Educational Research Services of the University of Alberta.

CONCLUSIONS

The specific conclusions relating to each hypothesis re to be found in Chapter 4. On the basis of this information, the following general statements may be formulated:

Any one of the three quantification abilities length, mass and time, is a better indicator of an individual's

ability in the performance of tasks involving the other two quantification parameters than any of the other variables studied. A high degree of relationship evidently exists between the three areas of measurement ability.

Knowledge of an individual's age grade in elementary school, previous experience or general intelligence quotient greatly aids in the prediction of that individuals potential success in the performance of quantification tasks.

The primary mental skills (from which the general intelligence quotient is derived) which help most in indicating an individual's ability in quantification include: spatial relations ability, verbal ability and perceptual speed ability, in descending order of importance. It was also determined that knowledge of an individual's numerical ability, as measured by the S.R.A. Primary Mental Abilities Test, was not a predictor of quantification skill. Furthermore, reasoning ability was a predictor only of those quantification skills related to time.

The teacher's rated perception of a student's ability in science helped only minimally in predicting quantification ability.

Knowledge of the family wage-earner's occupation, a measure of socio-economic status, did not aid in the prediction of an individual's quantification ability.

Knowledge of an individual's sex did not aid in prediction, except minimally in the case of mass quantification ability. It is thought, however, that sample bias may have

brought about this latter result.

A greater difference was found to exist in quantification score between one grade level and the next than was found to exist between the high, average and low I.Q. groups in any given grade. With respect to I.Q., the high I.Q. groups generally scored higher than the average I.Q. groups, and the average I.Q. groups obtained higher scores than the low I.Q. groups. Significant differences in score were found to occur most often between the high and low I.Q. groups in each of the grades. The small number of students in many of the I.Q. groups as defined may, however, have reduced the number of statistically significant differences.

For the sample of children studied, it was concluded that sex was not significant with respect to ability in the performance of the quantification tasks, other than in a few cases. No particular reasons could be found to account for these cases, although in each of the four instances in which significance occurred, boys performed better than girls. Sample bias, in all probability, contributed to this finding.

The most significant results of the study were provided with respect to hypothesis #4. Comparison of each grade with every other grade on each of the three quantification subtests indicated that there is a <u>gradual</u> and continual significant improvement in quantification ability extending at least to grade six, except between grade one and grade two, where the improvement is <u>very rapid</u>. These results confirm Vinacke's (1952) findings with respect to the de-

velopment of concepts. General agreement with Piaget (1960), Lovell (1962), and other 'Piagetian' researchers also exists.

A noteworthy finding, when comparison of grades was made, was the sudden rapid increase in quantification ability which occurred between grades one and two for all three quantification parameters at the mean age of 7 years 6 months. This finding tends to corroborate the findings of Piaget and his collaborators (1960) which indicate that beyond the age of 7, the fundamental concepts necessary for measurement, especially that of conservation, have been mastered. This is of considerable interest if it is recalled that the usual tests of conservation were not employed in this investigation, as had been the case in previous studies. Very different procedures (comparable to standard laboratory practice) were utilized, and yielded comparable results to the generally psychologically-based standard procedures for the measurement of the attainment of conservation.

Conclusions with regard to performance on the quantification subtests for each question and for each choice of measuring instrument are presented in Chapter 4, pages 93 to 105. Further discussion of these conclusions is unnecessary.

IMPLICATIONS FOR TEACHING AND EVALUATION

Certain implications may be drawn from this investigation:

The average quantification scores for each of the three physical parameters length, mass and time, determined

for each of the elementary grades, should prove to be helpful as a basis for comparison and for the evaluation of the quantification abilities of other elementary classes as determined by this, or similar, quantification tasks. In this context, the average score given for each grade for each question on the quantification instrument will also be of great use as a basis for comparison and for the determination of particular areas of strength and weakness in the performance of quantification tasks of other elementary science classes. The criterion averages may also prove to be useful as a basis for comparative studies of the growth in quantification abilities of children exposed both to the 'traditional' and to the inquiry skill approaches to the teaching of science. The results also carry the implication that experiences designed to improve quantification skills should be presented throughout the first six grades as no levelling off in growth of quantification ability through these grades is indicated by this study.

A further implication is that experience with measuring instruments is necessary for optimal development of quantification abilities. Concrete manipulative experience definitely aids in the development of the concepts and skills necessary for the completion of quantification tasks.

Boys and girls both appear to have the same general ability, and demonstrate the same general development, with respect to quantification skill. Students of low I.Q. may need special attention in order to optimize development of

all areas of quantification ability, however, as they lag significantly behind the high I.Q. group in these abilities.

A test using an instrument such as that used in the investigation could help in the prior identification of weaknesses with respect to quantification ability in any of the three physical parameters for any individual or group. Such weaknesses in quantification ability, if noted, could be countered by a remedial program which possibly might include use of exercises involving spatial relations ability, verbal ability, and perceptual speed ability. It would appear that numerical exercises would be of little assistance in the correction of weaknesses and the development of quantification abilities. Manipulative experiences with appropriate measuring instruments might also help to bring about an improvement in such abilities, as is indicated by the 'prior experiences' factor revealed by this investigation, although such experiences should not be introduced too soon (See page 45).

SUGGESTIONS FOR FURTHER RESEARCH

This study showed that the elementary grades possessed growing ability with respect to quantification of the physical parameters length, mass and time. Comparable research related to other physical parameters such as area, volume, temperature, force and electric current, to name a few, would be a fruitful undertaking. A more complete picture of a student's quantification abilities would then be realized.

Investigation shows that quantification ability appears

to improve, at least up to the grade six level, for the physical parameters studied. A similar study involving students through the remaining grades should be carried out in order to complete the study of development in this skill.

A much lower relationship was found to exist (than might have been anticipated) between numerical ability and quantification ability. It would seem worthwhile to undertake a further, more detailed study of the reasons for this somewhat surprising situation.

Relationships were found to exist between quantification skill and the variables verbal ability, spatial relations ability, perceptual speed ability, previous experience and teacher's perception of the child's ability in science. Further research into the nature of the relationships between quantification ability and these variables should increase knowledge with respect to procedures available for improving quantification skill.

Boys showed some superiority over girls with respect to length quantification in grade three and in time quantification in grade one, and mass quantification in grades one and four. Further research pertaining to the sex variable, through replication studies, might clarify these relationships and indicate possible sources of bias or error.

The present study served mainly to give an indication of the present average quantification ability of each of the elementary grades. The effect on quantification ability of the implementation of the new elementary science curriculum, or other changes that may take place in the future, may be

determined by further research of a similar type, carried out approximately three years from the date of this study. The comparison of the results of such research with the results of this study may well indicate the change in quantification ability that has taken place as a result of the implementation of curricular and/or other changes and innovations.

The new elementary curriculum guide speaks of twelve process skills, quantification being but one of these. To build up a significant body of knowledge concerning all of the process skills so that a systematic improvement of the science curriculum may eventually result, research of a similar type should be carried out on each of them. It is clear that a great deal of research and development work will have to be completed before a total picture of process skills, and of their acquisition in the elementary school, is obtained.

Once this task has been accomplished, still further research will be needed in order to develop simple and effective measuring devices which can be administered to whole classes of children at one time, devices which will give a complete profile of the developmental level of each of the process skills in each student. This investigation represents just one phase of the total program of work needed to meet the challenge of evaluating the process skills of science.

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APPENDIXES

APPENDIX A

Process Skills (Methods of Inquiry)

(as adapted from the Curriculum Guide, 1969, pp. 7-9)

PROCESS	DESCRIPTION OF BEHAVIOR
Basic Processes	
Observing	The desired pupil behavior is increasing competence in using not only his sense of sight but also his other senses of hearing, touch, smell and taste.
Classifying	The desired pupil behavior is increasing competence in grouping articles, objects and ideas on the basis of some observable property or properties.
Quantifying	The desired pupil behavior is increasing competence in measuring length, weight, area, volume, and rate of change of the physical world.
Communicating	The desired pupil behavior is increasing competence in describing an experiment so that an individual who has not seen it can carry it out.
Inferring	The desired pupil behavior is increasing competence in drawing more than one inference from a set of data, demonstrating that inference can be tested by further observation, and demonstrating that an inference can be tested by applying known tests to the properties of objects. Pupils should indicate that they are able to distinguish between observations and inferences.

Basic Processes

Predicting	The desired pupil behavior is increasing competence in conducting experiments to test predictions of relationships between two measurable quantities.

Integrated Processes

Formulating Hypotheses	The desired pupil behavior involves developing increasing competence in stating a hypothesis regarding causes of a phenomenon or the relationship between two variables. A hypothesis tells how to observe an expected outcome of an experiment.
Making Operational Definitions	The pupil should demonstrate increasing competence in stating the minimum things to do or look for in order to identify the subject being defined.
Controlling and Manipulating Variables	The desired pupil behavior is increasing competence in arranging conditions so as to be able to deliberately control and manipulate objects or conditions in an experiment.
Interpreting Data	The desired pupil behavior is increasing competence in getting the most out of data without oversimplifying, drawing conclusions supported by the data, and considering alternative explanations.
Formulating Models	The desired pupil behavior is increasing competence in building both physical and mental models to account for phenomena.

<u>Integrated Processes</u>

Experimenting	The desired pupil behavior is increasing competence in planning, conduction and communicating experiments in which the problem is clarified, hypotheses are stated, observations are made, and data is interpreted. This process depends upon the pupil being able to use all of the other processes.

APPENDIX B

DESCRIPTION OF SCHOOLS PARTICIPATING IN STUDY[1]

QUESTIONNAIRE

The purpose of this questionnaire is to determine practices and preferences in regard to science instruction.

The aim of the questionnaire is to gather information about the schools in general and not about particular schools. <u>All replies will be treated confidentially</u>.

Please answer the following questions as accurately as possible.

Thank you for your help in this study.

I. General Information

1. School ______________________________

2. System ______________________________

3. Grade Range ______________ Number of Teachers __________

4. Number of Classrooms in School

1	2	3	4	5	6

Number of Pupils in Classrooms

1	2	3	4	5	6

5. Total Elementary Rooms ______ Year School Opened _______

6. Total Elementary Pupils ______________________

7. Teaching Strategies Employed ______________________

____

[1]Blench, W.A., <u>A Study of the Teaching of Science in the Elementary Schools of Alberta</u>, Unpublished M.Ed. Thesis, University of Alberta, 1967.

8. Nature of District ______________________________

9. Other Comments ______________________________

____

10. Number of Minutes Science Taught per Week:

Grade One ______________________

Grade Two ______________________

Grade Three ______________________

Grade Four ______________________

Grade Five ______________________

Grade Six ______________________

II. Practice in Regard to the Teaching of Science in Your School

1. Check the item below which best describes how science is taught in your school at each of the indicated levels.

	GRADE LEVEL 1	2	3	4	5	6
(a) Science is taught by the classroom teacher.						
(b) Science is taught by a classroom teacher in the school as part of a system of departmentalization or semi departmentalization in which teachers "trade" subjects.						
(c) Science is taught by a special science instructor who is a member of the school staff.						
(d) Science is taught by a visiting specialist employed by the district or school system.						
(e) Another plan entirely different from those mentioned in (a) to (d) above.						

(If item (e) above has been checked, please explain.)

____

____

2. How is science teaching organized in your school? Please check one of the items below at each of the appropriate grade levels.

	GRADE LEVEL 1	2	3	4	5	6
(a) As a separate subject.						
(b) Completely integrated with other subjects.						
(c) Taught primarily as a separate subject but with appropriate integration and correlation.						
(d) Other						

(If you have checked (d) above please explain below.)

____

____

3. If science is <u>integrated</u> with other subject areas, indicate at the appropriate grade level the subject with which science is integrated.

GRADE LEVEL	Science integrated with subject named below
1	
2	
3	
4	
5	
6	

4. Is a science specialist employed by your unit or school system to give assistance to teachers in planning and teaching science?

Yes__________ No__________

(The above refers to science consultants or supervisors hired for the purpose of helping teachers through in-service work, demonstration lessons, planning programs, etc. If part time or other personnel are engaged in this function please explain)

____

____

III. Preference in Regard to Organization for Instruction in Science

1. Check the item below which best describes the organizational plan which you would prefer for instruction in science in your school at each of the indicated grade levels

	GRADE LEVEL					
	1	2	3	4	5	6
(a) Science taught by classroom teacher.						
(b) Science taught by the classroom teacher in the school as part of a system of departmentalization or semi-departmentalization in which teachers "trade" subjects.						
(c) Science taught by a special science instructor who is a member of the school staff.						
(d) Science taught by a visiting specialist employed by the district or school system.						
(e) Another plan entirely different from those mentioned in (a) to (d) above.						

(If (e) above is checked please explain your plan.)

____

____

2. Has your school the following facilities or equipment for science instruction?

	Yes	No
(a) Separate room for science instruction?	___	___
(b) Tables that can be used for science demonstrations?	___	___
(c) A portable science demonstration cupboard or unit?	___	___
(d) Sink and water supply in rooms?	___	___
(e) Other facilities	___	___

(If (e) above has been checked "yes" please specify these facilities in spaces below.)

____

____

3. Has your school the following A/V facilities or equipment for science instruction:

	Yes	No
(a) An overhead projector?	___	___
(b) A filmstrip projector?	___	___
(c) A 16mm. film projector?	___	___
(d) Projection screens?	___	___
(e) Models (plastic, metal, cardboard, etc.)?	___	___
(f) Transparencies of scientific teaching material?	___	___
(g) Other?	___	___

(If (g) above has been checked "yes" please specify these facilities in the spaces below.)

____

____

____

____

4. Indicate your rating of science as to the contribution it can make to the objectives of the total elementary school program. Please rate science at <u>each</u> grade level.

	GRADE LEVEL					
	1	2	3	4	5	6
Excellent						
Very Good						
Good						
Fair						
Poor						

Have you any suggestions as to how the science program might be improved in your school? ______________________

____

____

5. Has your school the following printed materials for science instruction:

	Yes	No
(a) One authorized series of science textbooks for each grade?	___	___
(b) More than one authorized series of textbooks?	___	___
(c) Additional series of science textbooks not authorized but used as enrichment?	___	___
(d) Science charts (e.g. The Earth's Crust)?	___	___
(e) Other materials?	___	___

6. The science equipment used in the elementary school is obtained for daily classroom use in the following manner: (check one please)

(a) Borrowed from the Junior High School. ___

(b) Obtained from a science storage room or cupboard in the school. ___

(c) Obtained from storage in the classroom where science is taught. ___

(d) Requisitioned from the school district for a specified period of time. ___

7. Which plan or plans are used in your school in teaching science: (please check for each grade level)

	GRADE LEVEL 1	2	3	4	5	6
(a) A course set out in Provincial curriculum guide.						
(b) A course prepared locally for your district.						
(c) A course as outlined in one of the authorized series.						
(d) A course selected according to the interests of the classes.						
(e) No formal course of study.						
(f) Other.						

(If (f) above has been checked please specify in the spaces below.)

___

___

___

School One | Grade Range 1-6 | Teachers 12

1. Nature of District: Middle class, new district

Grade	Number of Classrooms	Number of Pupils	Minutes Science Taught per Week
One	3	73	30
Two	3	72	50
Three	1	58	50
Four	1	49	50
Five	2	39	90
Six	1	30	90
Total	11	325	

2. Teaching Strategies Employed: Beginners - integrated program / years 2 and 3 - two teachers team for individualized program / years 4,5,6 one teacher, individualized conceptual program.

3. Teaching Strategies With Regard to Teaching of Science:

	Present Practice	Preference
a) Classroom Teacher:	Grade 1	Grade 1
b) Some form of departmentalization:	Grade 2,3	
c) Resident science specialist:	Grade 4,5,6	
d) Visiting science specialist:		

4. Facilities:

a) General - All but portable demonstration cupboard or sink
b) A/V Facilities - All as outlined in questionnaire.
c) Printed Materials - All as outlined in questionnaire.

5. Plan Used in Teaching of Science: A course set out in Provincial curriculum guide, and a course selected according to the interests of the classes for all grades.

6. Contribution of Science to Objectives of Total Elementary Program: For all six grades, very good.

School Two | Grade Range 1-6 | Teachers 20

1. Nature of District: New district, primarily one family dwellings with one large condominium complex and some subsidized public housing units.

Grade	Number of Classrooms	Number of Pupils	Minutes Science Taught per Week
One	4	97	60
Two	3	99	60
Three	4	96	60
Four	3	81	60
Five	2	78	90
Six	2	52	90
Total	18	503	

2. Teaching Strategies Employed: Use of science room -Co-operative teaching teams in Div. II - Div. I generally self contained graded programs.

3. Teaching Strategies With Regard to Teaching of Science:

	Present Practice	Preference
a) Classroom Teacher:	Grade 1,2,3	Grade 1,2,3
b) Some form of departmentalization:	Grade 4,5,6 (team teaching)	Grade 4,5,6 (team teaching)
c) Resident science specialist:		
d) Visiting science specialist:		

4. Facilities:

a) General- All as outlined in questionnaire.
b) A/V Facilities-All plus VTR and camera.
c) Printed Materials- All as outlined in questionnaire.

5. Plan Used in Teaching of Science: A course set out in Provincial curriculum guide with some emphasis on a course selected according to the interests and needs of the classes.

6. Contribution of Science to Objectives of Total Elementary Program: For all six grades, very good.

School Three Grade Range 1-6 Teachers

1. Nature of District: Combination of middle and lower middle class, welfare apartments.

Grade	Number of Classrooms	Number of Pupils	Minutes Science Taught per Week
One	2	61	45-60
Two	1	52	60
Three	1	62	60
Four	2	65	60
Five	2	75	90
Six	2	65	90
Total	14	380	

2. Teaching Strategies Employed: Some self-contained classrooms, some departmentalization, and some individualization.

3. Teaching Strategies With Regard to Teaching of Science:

	Present Practice	Preference
a) Classroom Teacher:	Grade 1,3,4,5,6	Grade 1,3,4,5,6
b) Some form of departmentalization:	Grade 2,4	Grade 2,4
c) Resident science specialist:		
d) Visiting science specialist:		

4. Facilities:

a) General - All as outlined in questionnaire.
b) A/V Facilities - All but Models (plastic, metal, etc.)
c) Printed Materials - All as outlined in questionnaire.

5. Plan Used in Teaching of Science: A combination of a course set out in Provincial curriculum guide and a course selected according to the interests of the classes at all levels.

6. Contribution of Science to Objectives of Total Elementary Program: Excellent at all grade levels.

School Four Grade Range 1-6 Teachers 131

1. Nature of District: Low socio-economic area with a very high rate of family breakdown. Many children have only one parent, and there is a high incidence of social assistance.

Grade	Number of Classrooms	Number of Pupils	Minutes Science Taught per Week
Spec	1	11	
One	2	50	
Two	1.5	38	
Three	1.5	38	80
Four	1.5	47	80
Five	2	43	80
Six	1.5	55	80
Total	10 (1 Special)	271 (11 Special)	

2. Teaching Strategies Employed: A nongraded program has been introduced in reading and arithmetic with the hope of extending this to all subject areas over the next two years.

3. Teaching Strategies With Regard to Teaching of Science:

	Present Practice	Preference
a) Classroom Teacher:	Grade 1,3,5	Grade 1,3,5
b) Some form of departmentalization:	Grade 2,4,6	Grade 2,4,6
c) Resident science specialist:		
d) Visiting science specialist:		

4. Facilities:

a) General-All as outlined in questionnaire
b) A/V Facilities-All but Models (plastic, metal, cardboard etc.)
c) Printed Materials- All but Science charts.

5. Plan Used in Teaching of Science: No formal course of study in grade one; a course set out in Provincial curriculum guide for grades 2,3,4,5,6.

6. Contribution of Science to Objectives of Total Elementary Program: Very good at grade 3,4; good at grade 1,2, and excellent at the grade 5,6 levels.

School Five | Grade Range 1-6 | Teachers 20

1. Nature of District: Lower middle to middle class area, no apartment houses in the area.

Grade	Number of Classrooms	Number of Pupils	Minutes Science Taught per Week
Kgn	1	41	
One	4	99	1440
Two	2	57	1500
Three	3	88	1500
Four	2	64	1500
Five	3	79	1500
Opportunity Rm.	1	13	
Six	2	58	1500
Total	18	458 (41 in kindergarten)	

2. Teaching Strategies Employed: Lower grade rooms are self-contained; middle grades (3,4) have some departmentalization; upper grades (5,6) are departmentalized to a greater extent.

3. Teaching Strategies With Regard to Teaching of Science:

	Present Practice	Preference
a) Classroom Teacher:	Grade 1,2,4	Grade 1
b) Some form of departmentalization:	Grade 3,5,6	Grade 2,3,4,5,6
c) Resident science specialist:		
d) Visiting science specialist:		

4. Facilities:

a) General- Do not have separate room, tables, sink and water.
b) A/V Facilities - All but Models (plastic, metal, cardboard)
c) Printed Materials - All as outlined in questionnaire.

5. Plan Used in Teaching of Science: A course as outlined in one of the authorized series for grades 1,2,3,4,5; a course prepared locally for district for grade 6.

6. Contribution of Science to Objectives of Total Elementary Program: Very good for grades 1,2; excellent for grades 3,4,5, 6.

School Six   Grade Range 1-6   Teachers 10

1. Nature of District: Low to middle class.

Grade	Number of Classrooms	Number of Pupils	Minutes Science Taught per Week
One	2	47	90
Two	1	31	90
Three	2	48	120
Four	$1\frac{1}{2}$	38	120
Five	$1\frac{1}{2}$	37	120
Six	2	42	120
Total	10	240	

2. Teaching Strategies Employed: Departmentalization in grades 4,5,6.

3. Teaching Strategies With Regard to Teaching of Science:

	Present Practice	Preference
a) Classroom Teacher:	Grades 1,2,3,4,5	Grades 1,2,3
b) Some form of departmentalization:	Grade 6	Grades 4,5,6
c) Resident science specialist:		
d) Visiting science specialist:		

4. Facilities:

a) General- None of the facilities as outlined in questionnaire.
b) A/V Facilities - All as outlined in questionnaire.
c) Printed Materials - All but additional series of science series of textbooks used as enrichment.

5. Plan Used in Teaching of Science: A course set out in Provincial curriculum guide for all grade levels.

6. Contribution of Science to Objectives of Total Elementary Program: Very good at all grade levels.

School Seven | Grade Range 1-9 | Teachers 21

1. Nature of District: Lower class, mostly first generation immigrants, educational aspirations leave much to be desired.

Grade	Number of Classrooms	Number of Pupils	Minutes Science Taught per Week
One	3	66	60
Two	2	51	60
Three	2	54	90
Four	2	59	90
Five	2	53	150
Six	2	58	150
Total	13	340	

2. Teaching Strategies Employed: A great deal of integration is being employed in the lower elementary division. Inquiry process is being employed in upper elementary division.

3. Teaching Strategies With Regard to Teaching of Science:

	Present Practice	Preference
a) Classroom Teacher:	Grade 1,2,3,4	Grade 1,2,3
b) Some form of departmentalization:	Grade 5,6	Grade 4,5,6
c) Resident science specialist:		
d) Visiting science specialist:		

4. Facilities:

a) General - All but sink and water supply in rooms.
b) A/V Facilities - All as outlined in questionnaire.
c) Printed Materials - All as outlined in questionnaire.

5. Plan Used in Teaching of Science: A course set out in Provincial curriculum guide for all grade levels.

6. Contribution of Science to Objectives of Total Elementary Program: Good at grade 1,2 level, very good at grade 3,4,5 grade levels, excellent at the grade 6 level.

School Eight | Grade Range 1-6 | Teachers $14\frac{1}{2}$

1. Nature of District: Upper middle class district with a section of students being bussed in from outlying areas.

Grade	Number of Classrooms	Number of Pupils	Minutes Science Taught per Week
One	3	65	30-60
Two	2	60	60
Three	2	49	90
Four	2	58	110
Five	2	63	110
Six	2	44	110
Total	13	339	

2. Teaching Strategies Employed: Various, demonstrations, group instruction, dividing into groups for experiments, individualized interest areas.

3. Teaching Strategies With Regard to Teaching of Science:

	Present Practice	Preference
a) Classroom Teacher:	Grade 1	Grade 1
b) Some form of departmentalization:	Grade 2,3,4,5,6	Grade 2,3,4,5,6
c) Resident science specialist:		
d) Visiting science specialist:		

4. Facilities:

a) General - All but a separate room for science instruction.
b) A/V Facilities - All as outlined in questionnaire.
c) Printed Materials - All but more than one authorized series of textbooks.

5. Plan Used in Teaching of Science: A course selected according to the interests of the classes for grade 1; a course as outlined in one of the authorized series for grades 2,3,4,5, 6.

6. Contribution of Science to Objectives of Total Elementary Program: Very good at all grade levels.

School Nine　　　Grade Range 1-7　　　Teachers 13

1. Nature of District: Mainly dairy farming area which is adjacent to City of Edmonton. Some land is being subdivided, the owners working in Edmonton.

Grade	Number of Classrooms	Number of Pupils	Minutes Science Taught per Week
One	$1\frac{1}{2}$	42	70
Two	$1\frac{1}{2}$	42	70
Three	$1\frac{1}{2}$	39	70
Four	$1\frac{1}{2}$	46	70
Five	$1\frac{1}{2}$	42	80
Six	$1\frac{1}{2}$	37	120
Total	9	248	

2. Teaching Strategies Employed: Home room teachers teach all subjects with following exceptions: (1) one grade 6 class departmentalized for ss., lang., sc., math. (2) all music taught by a special music teacher; (3) "trade off" for phys Ed and Art at grade 4 and 5 level.

3. Teaching Strategies With Regard to Teaching of Science:

	Present Practice	Preference
a) Classroom Teacher:	Grade 1,2,3,4,5	Grade 1,2,3
b) Some form of departmentalization:	Grade 6	Grade 4,5,6
c) Resident science specialist:		
d) Visiting science specialist:		

4. Facilities:

a) General- All facilities as outlined in questionnaire.
b) A/V Facilities-All but one authorized series of textbooks.
c) Printed Materials-All facilities as outlined in questionaire.

5. Plan Used in Teaching of Science: A course set out in Provincial curriculum guide for all levels.

6. Contribution of Science to Objectives of Total Elementary Program: Very good at all grade levels.

School Ten A | Grade Range 1-3 | Teachers

1. Nature of District: Rural.

Grade	Number of Classrooms	Number of Pupils	Minutes Science Taught per Week
One	Two portables and 9 classrooms for grades 1,2,3	259	60
Two			60
Three			60
Four			
Five			
Six			
Total	11	259	

2. Teaching Strategies Employed: Individualized classroom teaching.

3. Teaching Strategies With Regard to Teaching of Science:

	Present Practice	Preference
a) Classroom Teacher:	Grade 1,2,3	Grade 1,2,3
b) Some form of departmentalization:		
c) Resident science specialist:		
d) Visiting science specialist:		

4. Facilities:

   a) General - No separate room, tables or sink and water supply.
   b) A/V Facilities - All as outlined in questionnaire.
   c) Printed Materials - All as outlined in questionnaire.

5. Plan Used in Teaching of Science: A couse set out in Provincial curriculum guide for grades 1,2,3.

6. Contribution of Science to Objectives of Total Elementary Program: Good at grade 1, very good at grade 2,3 level.

School Ten B | Grade Range 3-6 | Teachers 15

1. Nature of District: Middle class, farmers and people living on acreages. Many of the residents commute to work in the City (Edmonton).

Grade	Number of Classrooms	Number of Pupils	Minutes Science Taught per Week
One			
Two			
Three	2	55	60
Four	3½	96	90
Five	3½	106	90
Six	4	110	90
Total	13	370	

2. Teaching Strategies Employed: Modified Joplin plan; special remedial room; semi-departmentalization.

3. Teaching Strategies With Regard to Teaching of Science:

	Present Practice	Preference
a) Classroom Teacher:		
b) Some form of departmentalization:	Grade 5,6	Grade 3,4,5,6
c) Resident science specialist:	Grade 3,4,5,6	
d) Visiting science specialist:		

4. Facilities:

a) General-All as outlined in questionnaire.
b) A/V Facilities-All as outlined in questionnaire.
c) Printed Materials-All as outlined in questionnaire.

5. Plan Used in Teaching of Science: A course set out in Provincial curriculum guide for grade 3,4,5,6; and a course selected according to the interests of the classes for grade 3,4,5,6.

6. Contribution of Science to Objectives of Total Elementary Program: Very good at grade 3,4,5,6 level.

School Eleven A | Grade Range 1-3 | Teachers 6

1. Nature of District: Urban and rural.

Grade	Number of Classrooms	Number of Pupils	Minutes Science Taught per Week
One	2	39	225
Two	1	35	90 correlation with lang. arts.
Three	2	48	120
Four			
Five			
Six			
Total	5	122	

2. Teaching Strategies Employed: No report cards; four interviews.

3. Teaching Strategies With Regard to Teaching of Science:

	Present Practice	Preference
a) Classroom Teacher:	Grade 2,3	Grade 2,3
b) Some form of departmentalization:	Grade 1	Grade 1
c) Resident science specialist:		
d) Visiting science specialist:		

4. Facilities:

a) General - All as outlined in questionnaire.
b) A/V Facilities - All as outlined in questionnaire.
c) Printed Materials - All as outlined in questionnaire.

5. Plan Used in Teaching of Science: A course set out in Provincial curriculum guide and a course selected according to the interests of the classes at all levels.

6. Contribution of Science to Objectives of Total Elementary Program: Excellent at grade 1; good at grade 3; fair at grade 2.

School Eleven B Grade Range 4-9 Teachers 18

1. Nature of District: Dairy farming, acreages, high-middle class.

Grade	Number of Classrooms	Number of Pupils	Minutes Science Taught per Week
One			
Two			
Three			
Four	2	51	114
Five	2	51	150
Six	2	49	150
Total	6	151	

2. Teaching Strategies Employed: Departmentalization as much as possible.

3. Teaching Strategies With Regard to Teaching of Science:

	Present Practice	Preference
a) Classroom Teacher:		
b) Some form of departmentalization:		Grade 4,5,6
c) Resident science specialist:	Grade 4,5,6	
d) Visiting science specialist:		

4. Facilities:

a) General - No sink and water supply in rooms.
b) A/V Facilities - All as outlined in questionnaire.
c) Printed Materials - All as outlined in questionnaire.

5. Plan Used in Teaching of Science: A course set out in Provincial curriculum guide for all levels.

6. Contribution of Science to Objectives of Total Elementary Program: Very good at all grade levels.

School Twelve Grade Range 1-6 Teachers 7

1. Nature of District: Most parents live on acreages, a small minority are dairy farmers. People living on acreages work in and around Edmonton.

Grade	Number of Classrooms	Number of Pupils	Minutes Science Taught per Week
One	1	20	80
Two	1	24	80
Three	1	23	105
Four	1	26	110
Five	1	28	90
Six	1	31	150
Total	6	152	

2. Teaching Strategies Employed: No team teaching considerable A/V instruction.

3. Teaching Strategies With Regard to Teaching of Science:

	Present Practice	Preference
a) Classroom Teacher:	Grade 1,3,4,5	Grade 1,2
b) Some form of departmentalization:	Grade 2,6	Grade 3,4,5,6
c) Resident science specialist:		
d) Visiting science specialist:		

4. Facilities:

a) General-No separate room, tables, cupboard or unit.
b) A/V Facilities- All as outlined in questionnaire.
c) Printed Materials- No authorized series of science text-books for each grade.

5. Plan Used in Teaching of Science: A course selected according to the interests of the class for grade 1, 2,3,4,5,6; and a course set out in Provincial curriculum guide for grade 2,3,4,5,6 levels.

6. Contribution of Science to Objectives of Total Elementary Program: Very good at all grade levels.

APPENDIX C

DESCRIPTION OF SCIENCE TEACHERS PARTICIPATING IN STUDY[1]

TEACHER QUESTIONNAIRE

The purpose of this questionnaire is to determine practice and preference in regard to science instruction.

The aim of this questionnaire is to gather information about the schools in general and not about particular schools. All replies will be treated confidentially.

Please answer the following questions as accurately as possible.

Thank you for your help in this study.

I. General Information

1. Name of school________________________________

2. Teaching grade(s)______________________________

3. Sex_______________________________________

4. Total number of years of teaching experience, including the present year. (circle one)

   1 - 3 4 - 6 7 - 9 10 or more

5. Total number of years of teaching experience, in the Elementary school, including the present year. (circle one)

   1 - 3 4 - 6 7 - 9 10 or more

6. Total number of years of education as for salary purposes. (circle one)

   1 2 3 4 5 6 more than 6

7. In which route was your professional education? (circle one)

   Elementary Secondary

---

[1]This questionnaire was adapted from Blench, W.A., A Study of the Teaching of Science in the Elementary Schools of Alberta, Unpublished M.Ed. Thesis, University of Alberta, 1967.

8. Number of science courses you have taken as part of your professional training.

____

(Count only those courses that are recognized as credit courses by the University and Department of Education for certification purposes, and beyond certification.)

II. Practice in Regard to the Teaching of Science in Your Classroom

1. Number of classrooms, including your own, to which you are teaching science.

	GRADE LEVEL						
	1	2	3	4	5	6	Total
Number of classrooms							

2. Check the item below which best describes how you teach science in your classroom and/or other classrooms, at each of the indicated grade levels.

	GRADE LEVEL					
	1	2	3	4	5	6
(a) Science is taught by the classroom teacher.						
(b) Science is taught by a classroom teacher in the school as part of a system of departmentalization or semi departmentalization in which teachers "trade" subjects.						
(c) Science is taught by a special science instructor who is a member of the school staff						
(d) Science is taught by a visiting specialist employed by the district or school system.						
(e) Another plan entirely different from those mentioned in (a) to (d) above.						

(If item (e) has been checked please explain below.)

____

____

3. How is science teaching organized in your classroom, and/or in other classrooms in which you teach science? Please check one of the items below at each of the appropriate grade levels.

	GRADE LEVEL 1	2	3	4	5	6
(a) As a separate subject.						
(b) Completely integrated with other subjects.						
(c) Taught primarily as a separate subject but with appropriate integration and correlation.						
(d) Other.						

(If you have checked (d) above, please explain below.)

____

____

III. Preference in Regard to Organization for Instruction in Science

1. Check the item below which best describes the organizational plan which you would <u>prefer</u> for instruction in science at the grade(s) level that you are presently teaching.

	GRADE LEVEL 1	2	3	4	5	6
(a) Science taught by the classroom teacher.						
(b) Science taught by a classroom teacher in the school as part of a system of departmentalization or semi-departmentalization in which teachers "trade" subjects.						
(c) Science is taught by a special science instructor who is a member of the school staff.						
(d) Science is taught by a visiting specialist who is employed by the district or school system.						
(e) Other arrangements (please specify below.)						

____

2. How would you prefer that science teaching be organized in your classroom? Please check one of the items below at each of the appropriate grade levels.

	GRADE LEVEL 1	2	3	4	5	6
(a) As a separate subject.						
(b) Completely integrated with other subjects.						
(c) Taught primarily as a separate subject, but with appropriate integration and correlation.						
(d) Other.						

(If you have checked (d) above please explain below.)

---

3. Check the term below which best describes your feelings of competence in teaching science at the grade level you teach.

	GRADE LEVEL 1	2	3	4	5	6
Excellent						
Good						
Adequate						
Below Average						
Poor						

4. Which plan is followed in your classroom in teaching science? (please check)

	GRADE LEVEL 1	2	3	4	5	6
(a) A course set out in Curriculum Guide for Elementary Science, 1969						
(b) A course prepared locally for your district.						
(c) A course as outlined in one of the authorized series.						
(d) A course selected according to the interests of your class.						
(e) No formal course of study.						
(f) Other. (specify)						

Findings 108 Teacher Questionnaires Answered.

1. Number of teachers per school teaching science in study:
   a) School One - 6; b) School Two - 14;
   c) School Three - 10; d) School Four - 7;
   e) School Five - 9; f) School Six - 7;
   g) School Seven - 9; h) School Eight - 10;
   i) School Nine - 9; j) School Ten - 16;
   k) School Eleven - 5; l) School Twelve - 5.
   Question not answered - 1.
   Total - 108 teachers.
   Average number of science teachers per school in study - 9.

2. Number of teachers for each elementary grade teaching science in study:
   a) Grade One - 31; b) Grade Two - 28;
   c) Grade Three - 26; d) Grade Four - 23;
   e) Grade Five - 23; f) Grade Six - 19.
   Total - 150 teachers.

N.B. Total teachers (150) for this question teaching science exceeds number of teachers in sample because some teachers teach more than one grade of science.

3. Number of teachers of each sex teaching science:
   a) Females - 78 teachers or 72.2%
   b) Males - 20 teachers or 18.5%
   c) No response - 10 teachers or 9.3%
   Total - 108 teachers or 100%.

4. Total years of experience for teachers in study:

a) One to three years	- 28 teachers	or 26.0%
b) Four to six years	- 17 teachers	or 15.7%
c) Seven to nine years	- 19 teachers	or 17.6%
d) Ten or more years	- 44 teachers	or 40.7%
Total	108 teachers	100 %

5. Total years of elementary school experience for teachers in the study:

a) One to three years - 29 teachers or 26.8%
b) Four to six years - 19 teachers or 17.7%
c) Seven to nine years - 17 teachers or 15.8%
d) Ten or more years - 42 teachers or 38.7%
e) No response - 1 teacher 1 %
Total 108 teachers 100%

6. Total years of training for salary purposes:
a) 1 year - 14 or 13%
b) 2 years - 28 or 26%
c) 3 years - 12 or 11%
d) 4 years - 38 or 36%
e) 5 years - 11 or 10%
f) 6 years - 1 or 1%
g) more than 6 years - 3 or 3%
Total - 108 teachers - 100%

7. Type of training for teachers in study:
a) Elementary Route - 88 teachers or 81.5%
b) Secondary Route - 20 teachers or 18.5%

8. Number of science courses taken by teachers in study:
a) 0 courses - 16 teachers or 15%
b) 1 courses - 34 teachers or 31.5%
c) 2 courses - 25 teachers or 23.2%
d) 3-5 courses 19 teachers or 17.6%
e) 6 or more - 5 teachers or 4.2%
f) no response 9 teachers or 8.5%
Total 108 teachers 100%

9. How science is taught by teachers in study:

	Grade						Total
Science Taught By	1	2	3	4	5	6	
a) classroom teacher	27	17	20	12	12	9	97
b) semi or full departmentalization	2	6	4	8	7	9	36
c) resident science specialist	0	0	1	0	1	0	2
d) visiting science specialist	0	0	0	0	0	0	0
e) other				2	2	2	6
Total	29	23	25	22	22	20	141

10. How science is organized in classrooms participating in study:

Method or organization	1	2	3	4	5	6	Total
	Grade						
a) as a separate subject	6	8	4	19	16	17	70
b) completely integrated	2	1	1	0	1	0	5
c) mainly as a separate subject with appropriate integration	24	16	19	8	4	4	75
Total	32	25	24	27	21	21	150

11. Preference of teachers in study with respect to science instruction:

Science taught by	1	2	3	4	5	6	Total
	Grade						
classroom teacher	15	4	11	5	2	2	39
semi or full departmentalization	10	10	6	3	9	8	46
resident science s specialist	6	8	8	13	14	13	62
visiting science specialist	1	1	0	0	0	0	2
Total	32	23	25	21	25	23	149

12. Preference of teachers with respect to classroom organization for science:

Method of organization	1	2	3	4	5	6	Total
	Grade						
as a separate subject	3	2	3	8	6	6	28
completely integrated	3	3	1	1	0	4	12
mainly as a separate subject with appropriate integration	24	15	19	14	16	12	100
Total	30	20	23	23	22	22	140

13. Feeling of competence in teaching science of teachers participating in the study:

	Grade						
Feeling	1	2	3	4	5	6	Total
Excellent	2	0	1	1	3	3	10
Good	7	12	14	12	12	9	66
Adequate	19	9	7	6	8	6	55
Average	2	2	1	0	1	1	7
Poor	0	1	1	0	0	0	2
Total	30	24	24	19	24	19	140

14. Plan followed with respect to teaching science by teachers participating in the study:

	Grade						
Plan followed	1	2	3	4	5	6	Total
Course in Curriculum Guide	14	8	10	14	11	13	70
Course prepared locally for district	0	1	1	0	0	3	5
Outline of an authorized series	13	8	8	3	6	3	41
According to interests of class	10	10	8	7	7	6	48
No formal course	1	3	2	1	0	1	8
Total	38	30	29	25	24	26	172[1]

[1]Total due to some teachers checking more than one response indicating that more than one plan is followed in many cases.

15. General suggestions for improvement of science program:

a) Science rooms are inadequate in design and area.

b) Science equipment is not adequate in terms of quantity.

APPENDIX D

KEY TO DATA SHEET

Questions 2-9:

Y - yes	N - no	
V - volunteer	R - response	P - prompt
C - correct	I - incorrect	

Question 6:

A - accurate   I - inaccurate

Question 9:

Name - refers to instrument name given by the student

Questions 10, 11, 13, 14:

a) Length

Yd - yardstick (meter stick)
12 - twelve inch ruler
6 - six inch ruler
Tp - sewing tape measure
Stp - retractable steel tape
Cl - calipers

b) Mass/Weight

Sp - spring balance
Bal - triple beam balance
PnB - pan balance
Sc - postal scale
El - elastic

c) Time

Cl - clock
StW - stopwatch
Met - metronome
Tm - Timer

Questions 12, 15:

C - correct procedure   I - incorrect procedure
U - units and numerical value correct

Question 15 Mass/Weight:

PnC - pan balance used to compare the weights of two blocks
PnW - pan balance used to weigh a block in ounces

Question 16:

Y - yes N - no
Name - refers to instrument name given by student

Question 17:

Rep - response that accuracy could be checked by personal repitition
Com Inst. - response that accuracy would be checked by different instruments and comparing results.
Other Per. - response that accuracy could be checked by comparison with another person's result

Question 18:

Sp - specific answer given
Gen - general answers given

Questions 19, 21:

Y - yes N - no

Questions 20, 22:

Inch R - ruler having inch units
Met R - ruler having metric units

Question 25:
Degree of difficulty
E - easy H - hard

Question 26:

Y - yes N - no

Project: K. Kellough - Quantification 1971 - Department of Elementary Education - U. of Alberta

Grade: Name: ____________ Room: ______ Tape Number: ______ Track: ______ Side: ______ Ft: ______

Age: ______ School: ________________

Question or Statement	Length 1 2 3	Mass 1 2 3	Time 1 2 3	Comments
1) What can you tell me about these things?	Time Start:	Time S:	Time S:	Warm-ups a)
2) Is there any difference? What?	Y C N I V R P	Y C N I V R P	Y C N I V R P	
3) What word tells us the way these things are different	C I V R P	C I V R P	C I V R P	
4) Can these things be arranged from ____ to ____?	Y N V R P	Y N V R P	Y N V R P	
5) Now arrange them!	C I V R P	C I V R P	C I V R P	
6) Can you guess the size of this ______?	A I Yellow V R P	A I Blue V R P	A I V R P	
7) How could you find out more about the size of ___?	C I V R P	C I V R P	C I V R P	
8) How could you find out the exact size of ______?	C I V R P	C I V R P	C I V R P	
9) What would you use to measure the ______?	C I Name V R P	C I Name V R P	C I Name V R P	
10) Which one of the things over there would you like to use to make the measurement?	Yd 12 6 Tp STp Cl	Sp. Bal PnB Sc El	Cl StW Met Tm	b)
11) What is the name of the thing you've chosen?	Yd 12 6 Tp STp Cl	Sp. Bal PnB Sc El	Cl StW Met Tm	
12) Now, make your measurement with it!	C I U	C I U	C I U	
13) Are there any other things on the table which you could use to make the same kind of measurement?	Yd 12 6 Tp STp Cl Y N	Sp Bal PnB Sc El Y N	Cl StW Met Tm Y N	
14) What are the names of the things you chose?	Yd 12 6 Tp STp Cl	Sp. Bal PnB Sc El	Cl StW Met Tm	
15) Now, I'd like you to use each of these other things which you've chosen to measure the ____ which we have here. First, I'd like you to use this and this!	Yd C I U Black 12 C I U Green 6 C I U White Cl. C I U Blue	Sp C I U Orange Bal C I U Yellow PnC C I U PnW C I U Red Sc C I U Blue El C I U Green	Cl C I U StW C I U Met C I U Tm C I U	
16) Are there any other things that you know of which are not on this table which you could use to measure these ______?	Y N Name:	Y N Name:	Y N Name:	
17) (a) How could you make sure that your measurement is right?/ (b) How could you check your measurement?	Rep. Com. Inst. Other Per.	Rep. Com. Inst. Other Per.	Rep. Com. Inst. Other Per.	
18) What other things that you know of can be measured in the same way?	Sp. Gen. Time End:	Sp. Gen. Time E:	Sp. Gen. Time E:	
19) Have you ever done any measuring like this before	Y Other: N	Y Other: N	Y Other: N	
20) What kind of measuring?	Inch R. Met. R. Tp	Sp Bal PnB Sc El	Cl StW Met Tm	
21) Have you ever seen anyone measure something before like you've just measured those?	Y N Other:	Y N Other:	Y N Other:	
22) What kind of measuring?	Inch R. Met. R. Tp	Sp Bal PnB Sc El	Cl StW Met Tm	
23) Can you tell the time?	Y N	24) What time does the clock say?	C I	
25) Degree of difficulty (hardness)	E H	S H	S H	
26) Did you know what we were trying to do?	Y N	Y N	Y N	
Score Tabulation Duration:	L	M	T	
Quantification Power Score				
Quantification Speed Score				
Composite Quantification Score				

I.D. Number: ________ Grade: ________ I.Q.: ________ Sex: ________

SUGGESTED REVISIONS TO QUANTIFICATION INSTRUMENT

As a result of the investigation the following revisions with respect to the quantification instrument are suggested:

1. Omit question 4 as it is redundant with question 5.
2. Omit question 7 as it is redundant with question 8.
3. Include a pendulum as an instrument to be used on the time subtest as it is an instrument commonly used to measure time duration in elementary school science experiments.
4. Replace the measurement using the twelve inch (30 cm.) ruler with one using the metric system of units as there is a trend to use metric units in scientific measurement.
5. Replace the seven inch stick with one which includes fractions of an inch (for example, six and three-eights inches) in order to indicate whether the student is able to measure in other than whole inches.
6. Omit question 11 as it does not measure quantification ability.
7. Omit question 14 as it does not measure quantification ability.
8. Include an intermediate category in question 17 between specific and general responses as many children suggest groups of things, a response

neither completely specific nor completely generalized (for example, the response "groceries" is intermediate to the specifics "bread" and "milk" and the generality "everything except...").

9. Question 24 with respect to telling time should include four parts, the same questions being asked of all students. The four parts might include: (a) telling whole hours for example seven o'clock; (b) telling half hours, for example three-thirty; (c) telling quarter hours, for example eleven forty-five; (d) telling time other than whole, half or quarter hours, for example one fifty-two. This hierarchical sequence would place each student at a particular level of telling time in accordance with Springer's findings (1952).

10. Omit the speed score and composite score (the quantification score divided by the speed score). These scores were found to be unmeaningful as the mean time durations in completing the interview for each grade level were approximately equal.

11. Include an activity during each subtest which indicates whether the student is a non-conserver, transitory conserver or conserver with respect to that parameter. Such information could be correlated with the quantification score possibly indicating more precisely the relationship between conservation and measuring ability.

KEY TO REVISED DATA SHEET

In addition to the symbols used on the data sheet (as explained on the data sheet key) the following new abbreviations are used on the revised data sheet.

Evidence of Conservation Activities:

N - nonconserver

C - conserver

T - transitory or partial conserver

Questions 8, 10: (Time Subtest)

P - pendulum

Question 14:

Int - intermediate stage between specifics and generalities

Question 19:

A - whole hours

C - quarter hours

B - half hours

D - other than whole, half or quarter hours

REVISED DATA SHEET

Project: K. Kellough - Quantification 1971 - Department of Elementary Education - U. of Alberta

Grade: | Name: ____________ Room: ______ | Tape Number: ____ Track: ____ Side: ____ Ft: ____

Age: ________ School: ____________

Question or Statement	Length 1 2 3	Mass 1 2 3	Time 1 2 3	Comments
1) What can you tell me about these things?	Time Start:	Time S:	Time S:	Warm-ups: a)
2) Is there any difference? What?	Y C / N I V R P	Y C / N I V R P	Y C / N I V R P	
3) What word tells us the way these things are different	C / I V R P	C / I V R P	C / I V R P	
4) Now arrange them!	C I V R P	C I V R P	C I V R P	
5) Can you guess the size of this ________?	A I Yellow V R P	A I Blue V R P	A I V R P	b)
6) How could you find out the exact size of __________?	C I V R P	C I V R P	C I V R P	
7) What would you use to measure the ____________?	C I Name V R P	C I Name V R P	C I Name V R P	
8) Which one of the things over there would you like to use to make the measurement?	Yd 12 6 Tp STp Cl	Sp. Bal PnB Sc El	Cl StW Met Tm P	
9) Now, make your measurement with it!	C I / U	C I / U	C I / U	
10) Are there any other things on the table which you could use to make the same kind of measurement?	Yd 12 6 Tp STp Cl / Y / N	Sp Bal PnB Sc El / Y / N	Cl StW Met Tm P / Y / N	Evidence of conservation length) N T C
11) Now, I'd like you to use each of these other things which you've chosen to measure the _____ which we have here. First, I'd like you to use this and this!	Yd C I U Black / M12 C I U Green / 6 C I U White / Cl. C I U Blue	Sp C I U Orange / Bal C I U Yellow / PnC C I U / PnW C I U Red / Sc C I U Blue / El C I U Green	Cl C I U / StW C I U / Met C I U / Tm C I U	mass) N T C
12) Are there any other things that you know of which are not on this table which you could use to measure these ____________?	Y / N / Name:	Y / N / Name:	Y / N / Name:	
13) (a) How could you make sure that your measurement is right?/ (b) How could you check your measurement?	Rep. Com. Inst. Other Per.	Rep. Com. Inst. Other Per.	Rep. Com. Inst. Other Per.	time) N T C
14) What other things that you know of can be measured in the same way?	Sp. Int. / Gen. / Time End:	Sp. Int. / Gen. / Time E:	Sp. Int. / Gen. / Time E:	
15) Have *you* ever done any measuring like this before	Y Other: / N	Y Other: / N	Y Other: / N	
16) What kind of measuring?	Inch R. Met. R. Tp	Sp Bal PnB Sc El	Cl StW Met Tm P	
17) Have you ever seen anyone measure something before like you've just measured those?	Y / N / Other:	Y / N / Other:	Y / N / Other:	
18) What kind of measuring?	Inch R. Met. R. Tp	Sp Bal PnB Sc El	Cl StW Met Tm P	
19) Can you tell the time?	Y N	20) What time does the clock say		A B C D / C C C C / I I I I
21) Degree of difficulty (hardness)	S H	S H	S H	
22) Did you know what we were trying to do?	Y N	Y N	Y N	
Duration:	L	M	T	
Quantification Power Score				

I.D. Number: __________ Grade: __________ I.Q.: __________ Sex: __________

APPENDIX E

WARM-UP ACTIVITY QUESTIONS

1. What can you tell me about these things?

2. Is there any difference? What?

3. What word tells us the way these things are different?

4. Can you arrange the things from __________ to _______?

5. Why did you put the things in that order?

APPENDIX F

PROCEDURAL INSTRUCTIONS FOR QUANTIFICATION TASKS

The following introductory statement will be made to each student:

"Hello! My name is Mr. Kellough. What is your name?... Hi____! How old are you?...When is your birthday?...What grade are you in______?... Which room is that?... What is your teacher's name?... Good!

I'm glad you are here today. I've picked you to help me find out about all these things you see on the two tables here. Would you like to help?...Great! Let's get started!

Oh! One more thing. This tape recorder here is going to record the things we say so I can recall everything we talk about. Have you ever spoken into a tape recorder before? ... Also, this piece of paper helps me remember the many things I want us to talk about. You will see me writing on it from time to time. Fair enough?

______, I've brought 5 groups of things with me today for us to look at together. We will be looking at one set at a time. I would like you to tell me all that you can about the things in each group. Later on I may ask you some questions about them. Before you tell me about the things in this group, you may look at them closely, you may handle them, you may even play with them to help you find out more.

You may also use the different things on this table here (point to the instruments) to help find out about these things (point to stimulus test objects) we are talking about. Feel free to look for anything you need. If you cannot find exactly what you want, maybe you can find something like it.

Do you understand what we are about to do?....Good! Let's try it with this group of things here..."

The following statements and questions will then be presented orally to the student with respect to each group of stimulus objects. The questions will follow the order given, unless the student offers the information voluntarily (in any sequence) in which case it will be noted and the appropriate questions will be omitted:

1. What can you tell me about these things?
2. Is there any difference? What?
3. What word tells us the way these things are different?
4. Can you arrange the things from ______ to ______?
5. Arrange them then.
6. Can you guess the size of _______?
7. How could you find out more about the size of _____?
8. How could you find out the exact size of ________?
9. What would <u>you</u> use to measure the ______?
10. Which one of the things over there would you like to use to make the measurement? (Investigator indicates measuring instruments available on adjacent table.)

11. What is the name of the name of the thing you've chosen?

12. Now, make your measurement with it!

13. Are there any other things on the table which you could use to make the same kind of measurement?

14. What are the names of the things you chose?

15. Now, I'd like you to use each of these other things which you've chosen to measure the _____ which we have here. First, I'd like you to use this and this!

16. Are there any other things that you know of which are not on this table which you could use to measure these ________?

17(a) How could you make sure that your measurement is right? or

(b) How could you check your measurement?

18. What other things that you know of can be measured in the same way? (Specific answers or ability to generalize.)

19. Have you ever done any measuring like this before? Did you use a ________? (Each instrument was indicated)

21. Have you ever seen anyone measure something before like you've just measured those? Did that person use a _________? (Each instrument was indicated.)

23. Can you tell the time?

24. What time does this clock say?

APPENDIX G

DESCRIPTION OF SCORING PROCEDURES

Four alternate and equally credible scoring procedures were utilized in this study in order to see whether the scoring procedure used produced significant differences in the findings of the study. The table below indicates that highly significant correlations exist between all scoring procedures employed. This basic similarity allows one to choose a 'preferred' procedure without altering the general conclusions derived as a result of the investigation.

PEARSON CORRELATIONS AMONG ALTERNATE SCORING PROCEDURES

		Length				Mass				Time			
		1	2	3	4	1	2	3	4	1	2	3	4
Length	1	1.00	.99	.99	.98	.77	.77	.77	.77	.78	.78	.77	.77
	2	.99	1.00	.97	.98	.78	.78	.77	.78	.78	.79	.76	.77
	3	.99	.97	1.00	.99	.76	.76	.75	.76	.78	.78	.76	.76
	4	.98	.98	.99	1.00	.77	.77	.76	.77	.78	.78	.76	.77
Mass	1	.77	.78	.76	.77	1.00	.99	.99	.99	.80	.80	.80	.81
	2	.77	.78	.76	.77	.99	1.00	.98	.99	.81	.81	.81	.82
	3	.77	.77	.75	.76	.99	.98	1.00	.99	.79	.78	.78	.79
	4	.77	.78	.76	.77	.99	.99	.99	1.00	.80	.80	.80	.80
Time	1	.78	.78	.78	.78	.80	.81	.79	.80	1.00	.99	.99	.99
	2	.79	.79	.78	.78	.80	.81	.78	.80	.99	1.00	.97	.98
	3	.77	.76	.76	.76	.80	.81	.78	n.80	.99	.97	1.00	.99
	4	.77	.77	.77	.77	.81	.81	.79	.80	.99	.98	.99	1.00

Because highly significant correlations existed between all scoring procedures, scoring procedure number one was arbitrarily chosen for all analyses discussed in Chapter 4. Below is a summary of each scoring procedure:

POSSIBLE SCORES FOR EACH QUESTION
ON EACH SUBTEST

	Scoring Procedure[1]			
Question	One	Two	Three	Four
1	--------- not scored ---------			
2	3,2,1,0	3,2,1,0	2,1,0	2,1,0
3	3,2,1,0	3,2,1,0	2,1,0	
4	--------- omitted ---------			
5	3,2,1,0	3,2,1,0	2,1,0	2,1,0
6	1,0	1,0	1,0	1,0
7	--------- omitted ---------			
8	3,2,1,0	3,2,1,0	2,1,0	2,1,0
9	3,2,1,0	3,2,1,0	2,1,0	2,1,0
10	1	1	1	1
11	--------- omitted ---------			
12	3,2,1,0	2,1,0	3,2,1,0	2,1,0
13	1 for each	1 for each	1 for each	1 for each
14	--------- omitted ---------			
15	3,2,1,0 for each	2,1,0 for each	3,2,1,0 for each	2,1,0 for each
16	1 for each	1 for each	1 for each	1 for each
17	1 for each	1 for each	1 for each	1 for each
18	2,1,0	2,1,0	2,1,0	2,1,0
19-26	--------- not scored ---------			

[1] See Chapter 2, pages 53-55 for a description of how the points were awarded.

APPENDIX H

TIMING OF THE VARIOUS PHASES OF THE STUDY

1. Pilot Study One - 9 hours (12 Students).
2. Pilot Study Two - 13.5 hours (18 Students).
3. Main Study - 125 hours (180 Students).
4. I.Q. Testing (Grades 1-3) - 15 hours (90 Students in twelve schools).
5. I.Q. Testing (Grades 4-6) - 23 hours (90 Students in twelve schools).

Total Data Collecting Time - 185.5 hours.

APPENDIX I

FREQUENCY OF EACH SCORE BY GRADE AND QUESTION

QUESTION TWO

	Score											
	Length				Mass				Time			
Grade	0	1	2	3	0	1	2	3	0	1	2	3
1	0	0	0	30	2	11	1	16	17	0	3	10
2	0	0	1	29	0	6	0	24	6	0	3	21
3	0	0	1	29	1	4	0	25	6	1	5	18
4	0	0	1	29	0	5	1	24	5	0	0	25
5	0	1	0	29	0	3	1	26	4	1	2	23
6	0	0	2	28	0	1	0	29	2	0	3	25
Total	0	1	5	174	3	30	3	144	40	2	16	122

QUESTION THREE

	Score											
	Length				Mass				Time			
Grade	0	1	2	3	0	1	2	3	0	1	2	3
1	27	1	1	1	27	3	0	0	0	0	0	0
2	27	0	3	0	18	0	3	0	28	0	1	1
3	24	0	5	1	10	5	7	8	27	3	0	0
4	18	5	5	2	2	10	13	5	22	3	3	2
5	10	7	8	5	2	2	16	10	19	5	4	2
6	1	6	17	6	1	1	17	11	16	3	8	3
Total	107	19	39	15	60	25	59	35	112	14	16	8

QUESTION FIVE

	Score											
	Length				Mass				Time			
Grade	0	1	2	3	0	1	2	3	0	1	2	3
1	1	3	16	10	3	11	15	1	11	11	4	4
2	0	0	20	10	0	7	23	0	6	7	8	9
3	0	1	19	10	3	4	20	3	5	9	13	3
4	0	0	21	9	2	3	24	1	4	6	10	10
5	0	0	18	12	2	3	23	2	3	1	17	9
6	0	0	18	12	0	3	25	2	5	3	10	12
Total	1	4	112	63	10	31	130	9	34	37	62	47

QUESTION SIX

	Score					
	Length		Mass		Time	
Grade	0	1	0	1	0	1
1	23	7	26	4	29	1
2	14	16	28	2	29	1
3	6	24	25	5	21	9
4	12	18	23	7	21	9
5	11	19	19	11	16	14
6	6	24	18	12	17	13
Total	72	108	139	41	133	47

QUESTION EIGHT

	Score											
	Length				Mass				Time			
Grade	0	1	2	3	0	1	2	3	0	1	2	3
1	11	2	3	14	12	0	5	13	22	1	4	3
2	1	0	6	23	2	1	7	20	11	5	3	11
3	1	1	2	26	0	0	2	28	7	2	3	18
4	0	0	1	29	1	0	1	27	7	0	5	18
5	0	0	1	29	0	0	0	30	2	0	1	27
6	0	0	3	27	0	0	1	29	0	1	4	25
Total	13	3	16	148	15	1	17	147	49	9	20	102

QUESTION NINE

	Score											
	Length				Mass				Time			
Grade	0	1	2	3	0	1	2	3	0	1	2	3
1	3	6	19	2	7	6	12	5	10	6	8	6
2	0	1	13	16	1	4	11	14	3	3	16	8
3	0	0	13	17	1	2	11	16	0	1	8	21
4	0	0	13	17	1	3	11	15	1	3	10	16
5	0	0	11	19	2	1	13	14	1	0	14	15
6	0	0	17	13	1	1	8	20	0	0	10	20
Total	3	7	86	84	13	17	66	84	15	13	66	86

QUESTION TEN THIRTEEN (LENGTH)

Grade	Score 0	1	2	3	4	5	6
1	0	0	3	6	11	10	0
2	0	0	0	2	6	21	1
3	0	0	0	6	9	14	1
4	0	0	0	1	4	24	1
5	0	0	0	0	6	22	2
6	0	0	0	1	3	25	1
Total	0	0	3	16	33	58	6

QUESTION TEN THIRTEEN (MASS)

Grade	Score 0	1	2	3	4	5
1	2	4	5	16	3	0
2	0	2	6	15	6	1
3	0	0	5	19	5	1
4	0	0	4	14	10	2
5	0	0	0	7	21	2
6	0	0	2	5	22	1
Total	2	6	22	76	67	7

QUESTION TEN THIRTEEN (TIME)

Grade	Score 0	1	2	3	4
1	5	1	3	18	3
2	0	1	5	16	8
3	0	2	4	19	5
4	0	1	2	23	4
5	0	0	2	19	9
6	0	0	7	7	16
Total	5	5	23	102	44

QUESTION TWELVE FIFTEEN (LENGTH)

Grade	Score 0	1	2	3	4	5	6	9
1	11	2	8	6	2	0	1	0
2	5	2	2	15	0	0	6	0
3	4	1	1	14	3	0	7	0
4	0	0	0	19	2	0	8	1
5	0	0	0	8	2	1	17	2
6	1	0	0	2	2	1	23	1
Total	21	5	11	64	11	2	62	4

QUESTION TWELVE FIFTEEN (MASS)

Grade	Score 0	1	2	3	4	5	6	7	8	9	10	11	12	13
1	6	3	4	13	2	0	2	0	0	0	0	0	0	0
2	1	3	2	12	5	2	0	3	2	0	0	0	0	0
3	0	3	1	8	7	2	3	3	3	0	0	0	0	0
4	0	0	0	3	10	4	2	7	0	0	2	1	0	1
5	2	0	0	0	6	1	0	5	6	2	3	2	0	3
6	2	0	0	0	1	1	2	7	2	1	4	4	1	5
Total	11	9	7	36	31	10	9	25	13	3	9	7	1	9

QUESTION TWELVE FIFTEEN (TIME)

Grade	Score 0	1	2	3	4	5	6	7	8	9	10	11	12
1	13	6	4	3	0	2	2	0	0	0	0	0	0
2	3	2	4	2	2	5	5	2	3	1	0	1	0
3	3	0	0	4	4	3	6	5	1	4	0	0	0
4	1	0	1	0	4	2	3	6	3	8	0	1	1
5	0	0	0	1	1	1	4	6	2	9	1	0	5
6	0	0	0	1	0	2	4	1	0	8	3	0	11
Total	20	8	9	11	11	15	24	20	9	30	4	2	17

QUESTION SIXTEEN (LENGTH)

Grade	Score 0	1	2	3
1	16	11	2	0
2	21	8	1	0
3	24	5	1	0
4	22	8	0	0
5	19	8	3	0
6	17	10	1	2
Total	119	50	9	2

QUESTION SIXTEEN (MASS)

Grade	Score 0	1	2	3	4	5
1	19	8	3	0	0	0
2	9	14	7	0	0	0
3	10	11	7	1	0	1
4	9	18	3	0	0	0
5	6	15	6	3	0	0
6	4	11	8	6	1	0
Total	57	77	34	10	1	1

QUESTION SIXTEEN (TIME)

Grade	Score 0	1	2	3	4
1	20	9	1	0	0
2	14	13	2	1	0
3	14	14	1	1	0
4	11	17	2	0	0
5	8	15	3	3	1
6	11	12	5	2	0
Total	78	80	14	7	1

QUESTION SEVENTEEN

	Score												
	Length					Mass				Time			
Grade	0	1	2	3	4	0	1	2	3	0	1	2	3
1	19	10	1	0	0	16	14	0	0	23	7	0	0
2	7	18	4	1	0	11	15	4	0	7	20	3	0
3	10	14	6	0	0	7	18	5	0	10	17	2	1
4	5	18	6	1	0	4	20	4	2	5	20	5	0
5	5	17	6	2	0	3	22	3	2	4	18	7	1
6	0	18	9	2	1	3	13	10	4	3	13	9	5
Total	46	95	32	6	1	44	102	26	8	52	95	26	7

QUESTION EIGHTEEN

	Score								
	Length			Mass			Time		
Grade	0	1	2	0	1	2	0	1	2
1	4	22	4	6	23	1	13	16	1
2	2	25	3	0	27	3	7	23	0
3	0	23	7	1	24	5	4	24	2
4	1	24	5	1	20	9	3	26	1
5	0	19	11	0	19	11	1	23	6
6	0	15	15	0	17	13	2	24	4
Total	7	128	45	8	130	42	30	136	14